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THE DISCHARGE OF DRAINS SERVING IRRIGATED LANDS

By

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INTRODUCTION

In the practice of irrigation, more water is often delivered to a project than is used by the plants, evaporated, or removed by natural drainage; a part must be removed artificially in order that all of the land may be cultivated. The removal of excess water by means of drainage systems has been necessary on numerous irrigation projects and will be required in many future developments. Among the important problems involved in the design of a drainage system is the determination of the quantity of water that must be removed and the required maximum rate of removal.

As irrigation agriculture develops and water becomes increasingly valuable, information relative to the total annual yield or run-off of drainage systems and the portion available for reuse during the irrigation season, becomes increasingly important. Careful estimates of required capacity are essential where underdrains are to be employed, and in deciding between the use of an underdrain and an open drain. Insufficient capacity results in overtaxing and perhaps failure, while a too generous design means excessive cost. Less care is required where an open drain is to be employed; however, an open drain should have capacity sufficient to prevent the submergence of the outlets of lateral underdrains if such exist. Moreover, outlet systems serving large areas underlaid with very permeable formations develop large quantities of water, and insufficient capacity may reduce their effectiveness with respect to lowering the water table to a proper depth.

One of the most useful aids in estimating the yield of a drainage system is information regarding other drains in its vicinity or other projects having conditions similar to the one being investigated. With the view of making such information available, data relative to the maximum discharge of many systems in 13 Western States are presented in this bulletin. These projects have an aggregate gross area of approximately 2,850 square miles, of which 2,100 square miles is irrigated. They contain a total of 2,550 miles of drain and 230 drainage wells.

Data are also presented on the total annual run-off from a gross area of 1,642,000 acres, of which 1,214,000 acres are irrigated. For most of this latter area the relation between annual run-off and total water applied is shown.

SUMMARY

The yield of a drainage system for any given period is equal to the deep percolation losses on the area, plus the natural underground inflow, minus the natural underground outflow, plus or minus the amount of decrease or increase of ground water. If the drainage system carries surface waste from farms this must be added. It is difficult, if not impossible, to determine the value of all these factors by direct methods. All may be changing at different rates, and some or even all may be changed by the installation of a drainage system. It becomes necessary to study other factors which exert either a direct or indirect influence, in order to arrive at an estimate of the required capacity of a proposed drainage system. Some of these factors are: Nature of soil, subsoil, and deeper formations; use of water and methods of applying it; crops grown; climatic conditions; topography; location and extent of the affected area; and the type of drainage system.

The nature of the formation at or near grade depths greatly influences, both directly and indirectly, the yield of drainage systems and this factor is used as a basis for classification. For the purposes of this report subsoils are divided into three main groups: (1) gravel, gravel and sand; (2) sand; and (3) clay, hardpan, and other dense formations. These groups are further divided into classes according to degree of permeability, and to some extent consideration is given to the nature of the subsoil and soil above grade depths.

For use in analyzing and comparing yields on a great variety of districts, the best data are obtained by taking total tributary irrigated area as a basis for showing yield per unit of area, and irrigation water diverted plus precipitation on irrigated area as a basis for showing the relation between annual yield and water applied.

Table 1 is a summary giving total area and miles of drain for the various districts considered, and weighted averages for all other factors. These averages, for a group of districts having an aggregate irrigated area of 1,113,646 acres, show that the annual yield is 30.9 per cent of the total water applied, and that 74.2 per cent of the annual yield is carried during the period from April to October, inclusive. They show that the annual yield is 1.84 acre-feet per acre, that the main irrigation system losses are 1.94 acre-feet per acre, that the sum of the water delivered to the land and precipitation is 4.01 acre-feet per acre, and that the difference between total water applied and drainage yield is 4.11 acre-feet per acre. This table also shows averages for three different groups based on the predominating nature of the subsoil.

Table 2 gives the maximum monthly rate of yield per square mile of tributary irrigated area and per linear mile of drain for each class of formation considered. It shows the lower and upper limits as well as the average for each class. The range of limits for each class is wide, partly because of difficulties of classification and of variation in permeability, but to a large extent because of variation in many other factors that influence the rate of yield. In some districts the effect of a majority of these factors may be a large yield, but in others the effect may be the opposite. In many projects the effect of some factors toward a large yield is offset by the effect of others in the opposite direction, with the result that the actual rate of yield is somewhere near the average for the class of formation considered.

GENERAL DISCUSSION OF DATA AND METHOD OF PRESENTATION

The data presented in Tables 3 and 4 were collected by many different districts and no doubt have varying degrees of accuracy according to the needs of each. Some projects have complete records covering many years, while others have made only a few measurements during one or more irrigation seasons. Some of the records are not recent and conditions with respect to both irrigation and drainage may have changed materially since the collection of the only figures available. Therefore the years during which the records were taken are shown. In some cases inadequate systems may have been improved or completed with the result that the discharge may be somewhat greater than the figures given for past years.

Table 1.- Summary of data on drainage yield compared to water applied for a year, and its monthly distribution for systems serving irrigated lands

	Tributary area		Length of drains	Irrigation water applied per acre		Precipitation	Total annual run-off		Weighted averages: Monthly run-off in proportion of year's total												Run-off for period, April to October inclusive in proportion of year's total
	Total	Irrigated		Delivered	Diverted		Per acre	In proportion of water diverted plus precipitation	January	February	March	April	May	June	July	August	September	October	November	December	
	Acres	Acres	Miles	Acre-feet	Acre-feet	Feet	Acre-feet	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
All districts 1/	1,641,906	1,213,581					1.93		5.0	4.8	6.1	7.3	10.7	12.2	12.7	12.5	10.8	7.6	5.5	4.8	73.8
All districts excluding those which pump from wells such data were available for those included in the totals given below	1,097,416	769,881	1,727.42				2.42		4.9	4.3	5.3	6.9	10.5	12.4	12.7	12.4	10.7	8.2	6.2	5.5	73.8
Districts for which data on water applied were available	1,472,136	1,113,646		3.27	5.21	.74	1.84	30.9	5.0	4.8	6.1	7.4	10.7	12.0	12.8	12.8	11.0	7.5	5.3	4.6	74.2
All districts excluding those which pump from wells	927,646	669,946	1,500.23	3.35	5.68	.75	2.35	36.5	4.9	4.2	5.1	6.9	10.5	12.2	13.0	12.7	10.9	8.2	6.0	5.4	74.4
Group: Predominating subsoil																					
1 Gravel or sand and gravel	385,427	295,210	443.81	4.12	5.80	.91	2.86	42.6	4.9	4.0	4.6	6.3	10.9	12.5	13.2	13.0	11.2	8.1	5.9	5.4	75.2
2 Sand	269,760	208,086	495.08	2.79	6.28	.53	2.39	35.1	5.0	4.9	6.6	8.6	10.4	10.9	11.5	11.1	10.2	8.4	6.6	5.8	71.1
3 Silt, clay, hardpan or other dense formation	217,850	135,088	455.68	2.50	4.07	.81	1.28	26.2	4.8	3.6	3.9	5.5	9.0	12.8	14.2	15.0	11.3	8.7	5.8	5.4	76.5

1/ Note: Data on water applied were not available on all of the districts included in the above totals.

Table 2.- Maximum yield, in various classes of formation, of representative drainage systems serving irrigated lands

Group	Predominating subsoil	Class	Description	Maximum average monthly rate of discharge of drains: Per square mile of tributary irrigated area: Low	Per square mile: Average	Per square mile: High	For mile of drain: Low	For mile of drain: Average	For mile of drain: High	Maximum daily discharge in proportion of maximum average monthly rate of discharge: Low	Average	High	Maximum monthly discharge in proportion of total annual discharge	Average length of drain per square mile of tributary irrigated area
				Sec. ft.	Sec. ft.	Sec. ft.	Sec. ft.	Sec. ft	Sec. ft.	Per cent	Per cent	Per cent	Per cent	Miles
1	Gravel or sand and gravel	A	Very permeable formation, very deep drains, drains of short length with large tribu- tary area, drains near reservoirs or close- ly parallelling canals in permeable for- mation				12.0	20.0	40.0		110			
		B	Permeable formation. Top soil sand or sandy loam	6.0	8.0	11.0	4.0	7.0	14.0	101	112	140	17.0	1.1
		C	Gravel containing much fine material, com- pact formation. Permeable formation of gravel or sand and gravel at grade depth with considerable clay or other dense for- mation above	2.0	4.0	6.0	1.0	3.0	5.5	105	116	150	16.0	1.3
2	Sand	A	Permeable formation. Top soil sand or sandy loam	4.5	6.5	8.5	3.0	4.5	7.0	103	112	120	15.0	1.4
		B	Fine sand or any sand with considerable dense formation and soil above	1.5	2.7	4.5	1.0	1.8	3.5	105	117	130	13.5	1.5
3	Clay, silt hard- pan or other dense formation	A	Sandy clay, stratified clay and fine sand with clay or silt predominating, layers of hardpan and fine sand. Top soil sandy loam	1.0	2.4	3.0	0.5	0.8	1.5	101		145	14.0	3 +
		B	Rather uniformly dense formation through- out, with heavy top soil	0.5	1.2	1.5	0.1	0.2	0.8	104		165	18.0	6 +

Table 3.- Drainage yield compared to water applied for a year, and its monthly distribution for systems serving irrigated lands

Name and location	Tributary area: Total	Tributary area: Irrigated	Irrigation water applied per acre: Delivered	Irrigation water applied per acre: Diverted	Precipitation	Total annual run-off: Per Irrigated	Total annual run-off: In percentage of water diverted plus precipitation	Date of measurement or of record	Run-off for year of record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Predominating subsoil
	Acres	Acres	Acre-feet	Acre-feet	Feet	Acre-feet	Per cent		Acre-feet	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
ARIZONA																						
Salt River Project (1)	240,000	230,700	3.51	4.87	0.35	1.16	22.2	1925	266,963	7.0	8.6	10.5	9.5	11.0	10.9	12.0	12.8	10.6	2.9	2.5	1.7	Caliche, clay, gravel
Yuma Project, Valley Division	53,120	41,126	3.38	4.44	.07	1.32	29.3	1924	54,471	6.4	5.8	7.5	8.7	9.8	10.3	10.6	10.2	9.0	8.1	6.8	6.8	Fine sand
CALIFORNIA																						
Yuma Project, Reservation Division	10,900	7,900	3.38	7.44	.07	1.41	18.8	1924	11,170	5.2	6.6	6.4	9.8	15.3	14.5	12.3	7.3	7.8	7.0	4.8	3.0	Do
Palo Verde Irrigation District	73,000	33,300			.34	2.77		1923-24	92,300	5.6	6.2	7.0	7.6	13.8	17.1	10.8	8.0	6.9	6.4	5.5	5.1	Sand
Modesto Irrigation District (2)	48,000	38,000	3.50	5.14	1.20	1.03	16.2	1926-27	39,107	0.6	6.4	11.3	7.0	13.6	15.6	15.1	14.2	11.3	3.6	0.7	0.6	Hardpan and sand
Merced Irrigation District(1)	75,000	45,000	3.00	4.49	1.06	1.26	22.7	1927	56,900	0.2	1.3	2.8	7.6	14.5	15.7	15.7	16.0	15.1	7.8	1.6	1.7	Do
Turlock Irrigation District (2)	181,490	130,000	2.39	3.67	1.10	.90	18.9	1927	116,855	6.0	6.1	8.6	9.6	10.1	9.5	10.7	10.8	10.4	9.7	6.2	2.3	Do
COLORADO																						
Prowers Co., Granada D.D.	8,000	7,000				1.83		1926	12,803	6.2	6.3	10.1	12.1	12.5	13.0	8.7	7.2	4.4	4.8	7.0	7.7	Varies
Prowers Co., Holly D. D.	10,000	9,000				2.89		1925-26	26,020	7.1	5.4	9.4	7.8	10.3	14.5	10.6	7.3	7.0	6.5	7.0	7.1	Do
San Luis Valley Carmel D.D.	5,740	3,320	2.71	3.37	.80	2.34	56.1	1915	7,760	3.8	3.2	4.8	9.1	9.2	12.3	15.4	11.0	8.4	9.2	8.1	5.5	Coarse sand and gravel
Do	5,740	4,000				2.12		1917	8,492	4.3	3.7	4.5	5.6	7.0	11.9	17.9	13.7	9.8	9.3	7.2	5.1	Do
San Luis Valley Rio Grande D.D.	34,000	15,000				1.72		1920	25,471	2.7	3.3	4.9	5.5	9.7	16.2	12.3	11.5	8.9	10.3	8.8	5.9	Do
Logan Co., Prewitt Drain.								1919-20	20,663	3.2	6.3	8.2	10.0	14.9	16.5	14.7	11.8	6.6	2.8	2.3	2.7	Do
Morgan Co., Bijou Drain.								1919-20	7,635	5.6	5.3	5.6	6.4	10.3	10.9	11.6	11.8	11.2	8.0	7.0	6.3	Coarse sand
Morgan Co., Shumacher Drain.								1919-20	5,698	4.7	4.8	5.7	9.7	7.8	10.4	12.3	14.2	11.3	7.8	6.0	5.3	Sand
Weld Co., Day and Smiley Drain.								1919-20	11,447	7.1	8.1	9.8	10.3	11.2	10.6	10.1	9.3	7.1	5.1	5.2	6.1	Medium to coarse sand
Farm near Grand Junction								1914-15	61	2.9	2.3	1.3	3.3	8.3	11.6	17.9	16.6	14.5	9.9	6.5	4.9	Shale
IDAHO																						
Ada Co., D.D. No. 2 (3)	31,000	28,000		6.95		2.99		1923	83,600													Gravel and sand
Ada Co., D.D. No. 3 (3)	4,200	3,900				1.55		1925	6,050													Do
Ada Co., D.D. No. 4 (3)	2,560	2,240				3.21		1925	7,180													Do
Minidoka Project. Total.	40,000	30,000	4.64	8.15	.65	3.16	35.9	1918	94,825	3.6	2.7	3.1	5.2	9.8	11.9	12.1	13.3	12.3	11.4	8.2	6.4	Sand
Drain D-3	2,305	1,720				4.53		1918	7,795	2.0	1.7	3.0	7.0	13.2	15.6	14.7	15.4	11.4	7.5	5.2	3.3	Do
Drain D-4	3,520	2,640				4.87		1918	12,853	3.1	2.3	4.4	9.4	13.0	12.0	12.9	13.2	10.7	8.2	6.2	4.6	Do
Drain D-5	2,305	1,720				1.99		1918	3,427	2.5	1.6	8.0	9.5	13.8	12.2	10.8	11.1	10.6	8.4	6.5	5.0	Sand and hardpan
Drain D-6-15-16	7,040	5,280				2.71		1918	14,299	3.0	2.2	1.8	4.6	11.4	14.1	11.2	15.6	13.1	10.6	7.5	4.9	Sandy
Drain D-13	385	290				2.04		1917	592	5.4	4.7	5.4	5.1	3.0	5.1	18.2	20.4	12.0	10.2	5.4	5.1	Do
Drain D-12	4,030	3,020				4.93		1916	14,902	4.4	5.3	3.7	4.1	11.3	12.9	16.6	14.5	15.1	3.0	5.2	3.9	Coarse sand
Main Drain Total	19,840	14,900				2.90		1918	43,139	4.0	2.7	2.3	3.8	8.3	10.9	10.9	12.1	13.5	13.9	9.7	7.9	Sand
Pioneer-Nampa-Meridian Dist/	152,832	135,000	4.19	5.02	1.13	1.69	27.5	1920	228,800	6.0	4.2	4.1	6.5	11.1	14.3	13.5	12.4	10.1	6.6	5.6	5.6	Coarse sand, sand and gravel
Dixie and West End Drains	14,976	13,400				2.57		1920	34,423	6.2	5.2	5.1	7.3	10.4	12.8	11.3	11.1	10.2	7.2	6.9	6.3	Sand and gravel
Wilson Creek System	37,312	29,500				2.67		1920	78,840	6.0	5.3	5.5	5.4	8.7	12.0	12.7	12.5	10.1	7.7	6.8	7.3	Coarse sand and gravel
Indian Creek System	20,864	18,800				1.66		1920	31,194	4.9	3.5	4.2	10.9	13.8	15.1	12.9	9.0	10.1	6.0	5.1	4.5	Sand and clay
Mason Creek System	42,112	38,300				1.34		1920	51,358	5.4	3.4	3.0	3.4	11.5	19.3	14.8	13.7	10.0	6.3	4.5	4.7	Gravel and sand
Five Mile System	37,568	35,000				.94		1920	32,985	7.3	2.3	1.0	9.4	14.6	12.8	16.5	15.0	10.1	4.4	3.1	3.5	Gravel and sand, compact
Boise Project, Lower Division																						
Fargo Basin	5,600	5,000	4.09	5.68	.75	1.66	25.8	1920	8,301	3.5	2.7	2.6	5.2	9.7	14.9	17.1	14.6	10.8	7.9	5.7	5.3	Sand and gravel
E. Alkali Drain	3,420	2,500				3.53		1920-21	8,831	8.5	6.4	4.6	5.4	7.2	7.9	9.1	10.0	10.5	10.7	10.0	9.7	
Griffith Drain	520	500				5.16		1921	2,580	1.9	1.3	0.9	1.6	10.6	16.6	18.2	18.6	14.9	7.7	3.7	4.0	Sand and gravel
Graber Drain	200	190				.97		1921	184	2.3	3.0	2.6	3.2	7.0	7.0	14.4	18.9	16.9	11.8	7.2	5.7	
Laht Drain	4,400	4,000				1.69		1921	6,744	4.3	3.9	4.1	6.3	9.7	11.0	13.4	15.8	11.8	8.1	6.2	5.4	Sand and gravel
L. Embk. Drain	2,432	1,900				2.49		1921	4,724	4.1	3.6	4.5	8.9	12.4	16.7	15.4	16.3	6.9	4.0	3.2	4.0	
Rose System	3,000	2,800				6.18		1920	17,290	7.8	6.5	6.5	5.6	6.8	9.8	11.9	12.3	11.5	9.3	6.7	5.3	Gravel
Scott Drain	1,100	700				6.32		1920	4,425	7.1	7.5	8.7	9.3	10.3	10.4	10.9	10.6	9.1	6.9	5.4	3.8	

Table 3.- Drainage yield compared to water applied for a year, and its monthly distribution for systems serving irrigated lands (Continued)

Name and location	Tributary area: Total	Tributary area: Irrigated	Irrigation water applied per acre: Delivered	Irrigation water applied per acre: Diverted	Precipitation	Total annual run-off: Per acre irrigated	Total annual run-off: In percentage of water diverted plus precipitation	Date of measurement or of record	Run-off for year of record	Monthly run-off in proportion of year's total: Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Predominating subsoil
	Acres	Acres	Acre-feet	Acre-feet	Feet	Acre-feet	Per cent		Acre-feet	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
IDAHO-OREGON																						
Boise Project Lower Division																						
Allen Drain	950	800				4.59		1920	4,042	5.8	5.1	5.5	5.2	6.2	8.3	11.5	12.2	13.7	10.2	8.5	7.8	Gravel
Riverside System	20,000	16,270				3.25		1920	52,800	4.6	4.2	5.5	6.3	8.0	10.0	11.6	12.1	11.9	11.0	8.2	6.6	Gravel sand and shale
OREGON																						
Boise Project Lower Division																						
Singer System	2,000	1,800				1.89		1920	3,410	3.2	3.5	5.6	6.7	8.5	10.6	12.6	13.2	12.3	10.9	7.3	5.6	Shale
S. Alkali Drain	2,100	1,900				3.26		1920	6,284	1.3	3.5	6.7	7.2	7.7	9.5	9.6	11.0	14.0	14.5	9.5	5.5	
Welch Drain	500	440				2.09		1920	920	3.4	3.2	2.7	2.6	5.6	12.5	15.0	15.3	14.9	12.7	7.4	4.7	Fine sand, silt and clay
MONTANA																						
Huntley Project	9,300	5,900	.97	1.73	1.44	1.09	34.4	1915	5,968	4.9	4.0	4.6	4.4	7.0	9.6	11.2	12.8	12.1	11.9	9.5	8.0	Clay, sand and gravel
Drain 2	235							1915	467	4.4	3.9	4.4	4.3	7.1	11.5	12.7	13.8	11.1	11.1	8.7	7.0	
Drain 4	25							1915	52	5.0	4.7	8.0	9.7	7.8	10.8	10.1	10.0	9.1	9.6	9.1	6.1	
Drain 5, 5-1	645							1915	487	4.0	4.4	4.2	4.4	8.1	11.1	12.3	13.6	12.8	10.6	8.2	6.3	
Drain 6	1,800							1915	829	4.7	4.1	6.8	4.6	6.0	5.1	11.4	14.4	13.4	13.2	9.1	7.2	
Drain 7	675							1915	577	5.9	5.3	5.1	5.0	7.6	11.5	11.6	11.8	11.0	9.4	7.8	8.0	
Drain 8	265							1915	222	2.7	1.7	1.9	1.7	5.7	12.5	14.9	15.7	14.5	13.4	9.1	6.2	
Drain 9	595							1915	441	4.8	4.5	5.8	5.9	7.0	9.8	9.9	12.4	11.0	9.6	9.9	9.4	
Drain 10	2,300							1915	768	4.6	3.6	3.8	3.6	4.7	10.7	10.4	12.2	14.5	14.4	10.1	7.4	
Drain 11	850							1915	514	6.7	3.6	4.3	3.1	4.9	8.7	9.6	12.0	12.8	12.9	11.7	9.7	
Drain 12	425							1915	650	6.4	5.1	6.0	6.6	7.5	9.7	9.0	9.0	6.1	10.5	12.2	11.9	
Drain 14	200							1915	213	2.5	3.9	2.0	5.5	20.0	8.2	10.9	14.1	12.0	9.1	7.2	4.6	
Drain 17	1,285							1915	748	4.4	3.0	2.8	3.1	6.7	9.8	12.1	14.4	14.4	13.3	8.6	7.4	
NEBRASKA																						
Lincoln Co., D.D. No.1	11,070	6,400				7.52		1926	48,100	6.6	4.0	5.3	5.4	7.2	9.4	10.5	13.8	10.8	10.0	8.7	8.3	Coarse sand, some gravel
North Platte Project																						
Interstate Division	79,400	51,000	2.63	4.95	1.13	2.63	43.3	1925	133,950	7.0	5.9	5.7	4.8	5.7	6.8	10.0	12.3	12.8	11.6	9.3	8.1	Fine sand, gr. & Brule clay
Sheep Creek	28,000	16,400				3.41		1925	55,990	7.9	7.5	7.4	6.1	6.8	6.9	7.7	9.6	10.1	11.3	9.6	9.1	Varies
Dry Spotted Tail	16,900	14,400				1.64		1925	23,600	5.6	3.9	3.9	3.1	5.0	7.9	11.4	13.6	16.7	12.4	9.2	7.3	Fine sand and gravel
Tub Springs	7,400	4,700				2.87		1925	13,470	6.9	4.4	4.2	4.3	5.3	5.4	11.5	13.4	13.9	13.1	9.8	7.8	
Dunham-Andrews	7,400	4,000				1.31		1925	5,220	5.4	4.3	2.5	2.2	2.5	5.4	14.3	16.9	15.8	13.2	10.0	7.5	Fine sand and Brule clay
Winters Creek	11,200	6,500				3.86		1925	25,080	7.1	5.8	5.7	4.9	5.0	6.6	10.4	14.0	12.8	10.9	8.9	7.9	Fine sand and gravel
Alliance	8,500	5,000				2.12		1925	10,590	5.5	4.9	4.3	4.0	5.7	6.8	13.8	15.7	14.8	9.9	8.4	6.2	
Minatare and L.Nine Mile	51,200							1925	86,500	6.2	2.5	3.9	3.9	4.4	6.3	10.9	14.2	15.4	12.2	10.1	10.0	
North Platte Project																						
Northport Division																						
Indian Creek	7,000							1925	10,650	4.6	3.6	4.1	4.0	4.1	4.0	12.5	19.0	20.9	10.3	7.2	5.7	
Silver Nail	4,500							1925	4,690	7.9	5.9	6.6	6.3	6.6	6.3	7.2	16.0	12.1	8.1	8.2	8.8	
WYOMING																						
North Platte Project																						
Ft. Laramie Division	44,800	18,000	2.06	3.85	1.13	1.06	21.3	1925	19,040	2.4	2.1	2.0	1.8	4.6	8.9	21.2	23.8	19.0	7.6	3.6	3.0	Tight formation
Cherry Creek	23,680	9,500				1.17		1925	11,070	2.6	2.3	2.5	2.1	4.5	7.4	22.0	22.9	18.9	7.6	4.0	3.2	
Pullen Drain	1,920	1,000				.52		1925	520	3.5	2.9	2.9	2.5	3.3	9.8	27.5	18.6	10.4	7.5	6.3	4.8	
Katzer Drain	19,200	7,500				.99		1925	7,450	2.2	1.7	1.1	1.2	6.0	11.1	19.5	25.5	19.7	7.4	2.9	2.7	

(1) Drainage water all pumped from wells.
(2) Drainage yield includes water pumped from wells and discharge from gravity drains.
(3) Totals are only for the period April to September, inclusive.

Table 3 .- Drainage yield compared to water applied for a year, and its monthly distribution for systems serving irrigated lands (Continued)

Name and location	Tributary area: Total	Tributary area: Irrigated	Irrigation water applied per acre: Delivered	Irrigation water applied per acre: Diverted	Precipitation	Total annual run-off: Per acre irrigated	Total annual run-off: In percentage of water diverted plus precipitation	Date of measurement or of record	Run-off for year of record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Predominating subsoil
	Acres	Acres	Acre-feet	Acre-feet	Feet	Acre-feet	Per cent		Acre-feet	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
NEVADA																						
Newlands Project, Total	96,000	44,887	3.25	6.66	.40	1.64	23.2	1923	73,534	2.3	2.3	2.2	6.6	10.8	16.2	15.7	17.1	12.0	7.3	4.4	3.1	
N. Carson Division, Total	6,400	3,296	4.66	16.57	.40	2.21	13.0	1923	7,282	3.8	2.9	2.4	4.3	9.3	14.1	16.8	17.7	14.1	6.2	4.9	3.5	Sandy
S. Carson Division, Total	80,000	35,824	2.66	5.15	.40	1.54	27.7	1923	55,246	2.2	2.4	2.3	7.0	11.0	16.9	14.8	16.6	11.5	7.8	4.5	3.0	
Kent Lake and Carson L.	19,200							1923	6,611	0.7	2.0	1.8	4.3	9.3	14.3	26.0	15.5	14.5	9.0	1.5	1.1	Heavy clay
S. Carson exclusive of two above	60,800							1923	48,635	2.4	2.4	2.3	7.4	11.3	17.3	13.3	16.7	11.1	7.6	4.9	3.3	
Truckee Division, Total	9,600	5,767	6.10	10.40	.40	1.91	17.7	1923	11,006	2.1	1.5	1.4	5.7	10.6	14.4	19.3	19.3	13.3	5.6	3.8	3.0	Sandy and gravel
Truckee Carson Experiment Farm								1913	16	3.1	4.6	10.2	17.3	21.6	11.4	6.6	4.9	5.9	5.2	4.2	5.0	
NEW MEXICO																						
Carlsbad Project	5,031	4,000	2.43	2.68	1.58	1.72	40.4	1919	6,879													Gypsum, sand and gravel
NEW MEXICO - TEXAS																						
Rio Grande Project, Total	170,240	130,911	2.16	6.52	.65	2.50	34.9	1925	327,113	5.2	5.5	7.7	9.8	10.9	10.8	11.5	10.5	9.5	7.3	5.9	5.4	Fine sand
Mesilla Division, Total	94,720	67,356	2.37	7.40	.65	2.99	37.1	1925	201,037	5.1	5.1	7.5	9.5	10.5	11.1	11.9	10.6	9.9	7.3	6.1	5.4	Do
Anthony Drain	4,480							1924	6,253	3.9	3.8	6.2	9.0	11.8	10.8	10.4	13.6	10.3	10.0	5.3	4.9	
Chamberino Drain	2,560							1925	5,051	3.7	4.6	8.5	9.4	10.4	10.6	12.0	10.4	10.4	8.5	5.9	5.6	
Del Rio Drain	17,920							1925	56,236	6.0	5.7	7.6	9.3	10.4	10.2	11.1	10.3	9.4	7.5	6.4	6.1	
East Drain	10,240							1925	17,284	5.3	5.1	6.9	8.6	11.1	11.1	12.9	12.0	10.1	6.9	4.9	5.1	
La Mesa Drain	6,400							1923	21,673	8.0	8.0	9.6	10.1	9.0	8.8	9.2	9.2	7.3	6.9	7.0	6.9	
Leasburg Drain	5,120							1923	14,971	5.2	4.9	9.0	10.3	12.2	13.1	12.2	9.6	8.2	6.7	4.3	4.3	
Mesilla Drain	10,240							1923	12,289	6.6	6.0	6.0	7.4	12.2	12.9	13.2	13.2	8.2	6.4	4.2	3.7	
Montoya Drain	4,480							1925	7,707	6.7	6.7	11.6	11.6	9.6	8.9	8.9	9.6	9.8	6.1	5.3	5.2	
Nemexas Drain	12,160							1925	21,287	5.4	5.4	8.7	10.2	10.3	9.2	9.3	9.0	9.8	9.0	8.1	5.6	
Picacho Drain	3,840							1923	8,573	9.2	9.2	9.0	8.4	9.5	8.9	8.9	8.5	7.9	7.4	6.4	6.7	
Selden Drain	2,560							1924	5,197	3.3	4.2	6.1	8.0	11.7	11.9	12.3	12.3	11.0	8.0	5.8	5.4	
West Drain	14,720							1925	29,765	3.6	3.9	6.5	9.8	10.4	14.6	14.2	10.3	10.5	5.5	5.8	4.9	
NEW MEXICO																						
Rincon Division, Total	12,800	9,344	1.85	5.31	.65	3.15	52.9	1925	29,436	5.5	5.3	7.2	8.3	11.4	11.2	11.5	11.6	9.2	7.1	5.5	6.2	Fine sand
Garfield Drain	6,400							1925	12,676	5.8	5.3	7.8	9.8	13.7	11.4	11.6	10.3	8.9	6.1	4.4	4.9	
Hatch Drain	3,840							1925	11,539	6.2	6.3	8.1	8.2	11.0	11.4	11.1	13.4	8.9	6.1	4.8	4.5	
Rincon Drain	2,560							1925	5,221	3.1	3.2	3.5	5.2	7.0	10.3	11.9	10.6	10.8	11.5	9.7	13.2	
TEXAS																						
Rio Grande Project																						
El Paso Division, Total	62,720	54,211	1.95	5.62	.65	1.78	28.4	1925	96,640	5.3	6.3	8.2	10.9	11.3	10.2	10.7	10.1	8.7	7.3	5.7	5.3	Fine sand
Alamo Drain	3,200							1925	7,883	5.2	5.9	7.1	9.8	11.2	12.4	9.8	11.3	8.6	7.4	6.2	5.1	
Border Drain	3,200							1925	4,197	2.2	3.7	9.8	10.5	11.6	12.5	12.6	9.1	9.2	7.4	5.8	5.6	
Fabens Drain	2,560							1924	10,773	6.0	4.8	3.7	10.2	11.4	12.2	11.4	12.0	10.0	5.7	6.1	6.5	
Franklin/Playa	9,280							1924	16,020	6.2	4.8	6.3	7.9	10.9	9.8	9.3	10.4	10.0	10.1	7.4	6.9	
Island Drain	6,400							1925	11,228	4.7	5.2	8.9	10.8	12.1	10.3	10.3	10.0	9.5	7.1	6.2	4.9	
Mesa Drain	12,800							1925	14,083	2.5	7.1	8.3	16.2	11.7	10.7	11.0	9.8	8.4	7.8	3.7	2.8	
Middle Franklin and Playa	21,120							1925	28,403	6.1	5.2	6.8	9.4	11.3	10.0	11.4	10.7	9.1	7.6	6.3	6.1	
Playa Drain	3,200							1923	10,219	7.7	5.9	6.8	9.4	9.0	8.8	9.0	9.0	8.4	9.1	8.5	8.4	
River Drain	7,040							1924	14,058	6.9	6.7	7.3	8.2	11.5	11.0	9.9	10.5	8.8	7.3	5.7	6.2	
Tornillo Drain	9,600							1925	16,695	6.9	8.5	9.5	10.5	12.4	10.3	10.9	7.9	7.5	5.9	4.9	4.8	
OREGON																						
Klamath Project	28,300	23,200	1.19	2.73	1.53	1.23	28.9	1924-25	28,580	9.5	2.3	5.7	1.6	6.9	11.6	16.4	17.2	6.4	7.1	6.1	9.2	Hardpan, chalk & fine sand
Nyssa Arcadia D. D.	7,298	4,439	2.93	4.64	.67	2.03	38.2	1918	9,007	5.7	5.7	6.7	7.6	10.1	10.9	12.2	10.2	9.1	8.1	7.1	6.6	Fine sand under hardpan
Umatilla Drainage District	3,800	3,600		6.30	.80	1.93	27.2	1923	6,932	3.1	4.4	6.2	7.3	12.4	15.0	14.2	11.5	8.2	3.7	6.0	8.0	Gravel and sand
Do	3,800	3,600		3.96	.67	1.56	33.7	1924	5,612	7.2	8.3	9.5	12.4	13.1	14.7	9.0	5.3	4.2	3.8	3.3	4.2	do
Umatilla Project, Main Drain	12,160	4,500	6.27	9.60	.55	8.30	81.8	1925	37,352	4.0	4.4	5.1	6.7	9.8	11.0	12.8	13.1	11.2	8.8	7.2	5.9	Sand and gravel
Do	12,160	4,500	4.59	8.38	.67	7.34	81.1	1924	33,000													Do

Table 3 .- Drainage yield compared to water applied for a year, and its monthly distribution for systems serving irrigated lands (Continued)

Name and location	Tributary area: Total	Tributary area: Irrigated	Irrigation water applied per acre: Delivered	Irrigation water applied per acre: Diverted	Precipitation	Total annual run-off: Per acre irrigated	Total annual run-off: In percentage of water diverted plus precipitation	Date of measurement or of record	Run-off for year of record	Monthly run-off in proportion of year's total: Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Predominating subsoil
	Acres	Acres	Acre-feet	Acre-feet	Feet	Acre-feet	Per cent		Acre-feet	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
WASHINGTON																						
Yakima Co. Drainage District	74,000	70,778				1.56		1923-24	110,722	4.8	4.4	4.5	6.4	9.4	11.5	12.1	12.0	12.5	10.5	6.6	5.3	
Yakima Co. Yakima Project, Sunnyside Division	60,300	57,813	3.30	4.24	.61	1.44	29.7	1923-24	83,149	5.6	5.2	5.0	6.7	9.0	10.7	11.0	10.6	11.5	11.1	7.4	6.2	
Yakima Co. Tributary to Sulphur Cr. W.W.	29,200	27,940	3.38	4.39	.48	1.40	28.8	1924-25	39,255	6.6	5.9	5.1	7.3	9.9	10.1	10.0	10.2	10.4	9.9	8.1	6.5	Hardpan with sand pockets
Yakima Co. D.D.No. Joint 1	2,300	2,175				.46		1923-24	1,003	3.9	3.4	3.3	4.8	8.4	10.7	12.5	13.5	13.3	11.9	9.2	5.1	Lava rock
No. 2	10,600	10,322	3.30	4.24	.61	1.20	24.8	1923-24	12,420	6.5	6.6	6.3	9.2	10.1	11.4	10.3	8.2	9.0	8.4	6.8	7.2	Hardpan and sand
No. 3 Main	10,900	10,157	3.30	4.24	.61	.79	16.3	1923-24	7,974	6.6	5.9	6.7	7.9	10.4	11.3	9.6	9.0	9.5	8.7	7.3	7.1	Hardpan with sand pockets
No. 3, Sub 5 and 6	2,400	2,289				1.12		1923-24	2,569	5.2	4.7	5.7	6.7	10.0	13.1	12.9	10.8	10.0	8.7	6.6	5.6	
No. 4	1,600	1,506				1.63		1923-24	2,449	4.0	3.9	4.8	4.6	8.7	13.6	16.3	14.7	12.7	9.0	4.1	3.6	Sandy loam and gravel
No. 5	2,250	2,108				1.68		1922-23	3,540	7.3	5.4	5.5	5.4	7.1	9.3	10.4	10.7	10.7	11.2	9.0	8.0	Hardpan
No. 7	3,850	3,516				3.32		1923-24	11,997	5.4	4.5	4.7	5.1	6.6	7.8	10.3	11.9	13.2	14.9	9.3	6.3	Sand, little hardpan
No. 9	8,150	7,965	3.18	4.30	.30	1.46	31.7	1922-23	11,658	6.2	4.7	4.6	6.1	8.6	10.6	10.3	10.2	10.9	12.0	8.6	7.2	Hardpan and sand pockets
No. 10	2,350	2,292				1.79		1923-24	4,105	5.6	4.6	5.3	6.2	8.2	9.9	10.6	12.2	12.2	10.7	8.0	6.5	Do
No. 11	6,600	6,353				1.53		1923-24	9,730	2.6	2.2	3.4	7.4	12.8	14.3	14.5	13.1	14.7	7.8	4.2	3.0	
No. 12	1,650	1,572				3.94		1923-24	6,185	3.8	3.2	3.6	4.5	8.1	11.9	14.6	14.2	14.2	10.7	6.6	4.6	Sand and hardpan
No. 13								1922-23	4,259	0.0	0.0	0.0	2.7	10.4	17.8	18.7	19.7	16.3	11.2	3.2	0.0	Gravel
No. 15	800	776				.39		1923-24	302	4.3	2.7	2.5	6.7	11.2	14.2	10.5	8.2	12.4	12.0	8.9	6.4	Silt
No. 16	730	698	3.18	3.80	.61	.59	13.4	1923-24	414	1.5	0.6	1.7	1.2	6.7	14.4	10.2	14.4	23.0	17.2	6.3	2.8	Do
No. 17	660	629				2.02		1923-24	1,269	5.9	4.8	4.8	5.3	8.0	11.0	9.5	11.3	12.9	11.3	8.3	6.9	Hardpan and sandy loam
No. 18	900	861				2.49		1923-24	2,140	6.5	6.3	7.5	5.2	8.0	10.3	11.5	11.6	11.1	9.4	6.4	6.2	Sand and hardpan
No. 19	780	742				1.77		1923-24	1,310	6.0	5.0	5.4	5.5	8.5	10.7	10.7	11.3	12.1	10.6	7.6	6.6	Hardpan
No. 20	960	954				1.74		1923-24	1,663	6.8	5.7	6.1	7.5	10.9	13.5	10.9	7.7	8.4	8.1	7.1	7.3	Hardpan
No. 24	1,150	1,092				4.22		1922-23	4,611	5.8	3.7	3.1	4.8	8.0	9.3	9.7	10.4	13.1	14.7	9.9	7.5	Gravel and sand
No. 25	3,700	3,575				.66		1922-23	2,367	6.5	5.4	4.1	4.5	10.1	13.2	10.3	13.7	11.2	8.7	6.3	6.0	Hardpan and silt
No. 27	1,200	1,121				.70		1922-23	781	3.3	2.2	2.5	9.5	11.8	11.9	12.8	15.0	10.1	10.9	5.9	4.1	Hardpan
No. 28	530	498				4.23		1923-24	2,107	0.4	0.2	1.0	2.5	7.9	14.7	13.3	25.8	22.1	9.4	2.0	0.7	Gravel
No. 29	500	409				.63		1923-24	259	7.0	5.6	5.3	6.1	7.3	7.8	9.8	11.9	13.7	9.7	7.4	8.4	Hardpan
No. 31	1,850	1,781				.97		1923-24	1,732	4.3	3.3	3.1	3.4	5.4	7.4	12.6	15.0	17.0	14.1	8.8	5.6	Hardpan, sand
No. 32	520	497				.84		1923-24	417	0.5	0.2	2.1	6.2	13.0	18.2	16.1	14.6	12.0	8.2	7.7	1.2	Hardpan
No. 33	1,100	995				4.04		1922-23	4,022	0.2	0.2	0.3	4.6	12.8	19.4	22.3	20.8	15.2	3.5	0.4	0.3	Gravel
No. 35	1,550	1,448				1,28		1923-24	1,856	6.6	5.7	5.7	4.2	6.6	9.1	10.3	11.5	12.6	11.4	8.8	7.5	Silt and sand
No. 38	1,000	943				1.13		1923-24	1,065	2.4	1.6	2.8	3.8	9.7	16.6	14.7	11.9	16.1	12.3	5.1	3.0	Hardpan, cement gravel
No. 40	670	658				1.11		1923-24	731	4.9	3.4	3.8	6.3	10.7	15.1	11.2	7.7	12.7	11.4	6.8	6.0	Do
Wapato Project, Total	100,000	73,290	5.44	8.16	.53	5.14	59.2	1925-26	377,000	4.0	3.5	4.9	7.2	13.0	13.1	13.2	12.8	10.9	7.9	5.0	4.5	Gravel
,Drains 1, 2, 3 and 4								1925-26	188,200	0.5	0.1	0.1	4.7	16.2	19.1	20.2	19.0	11.4	6.5	1.4	0.8	Do
WYOMING																						
Shoshone Project	47,856	30,460	2.26	4.07	.45	2.22	49.1	1923	67,537	1.4	1.1	1.1	1.1	9.2	17.6	21.1	20.2	15.4	6.7	2.8	2.3	Gravel quicksand, shale and sandrock
Area No. 1	6,239	5,200	2.04	3.56	.45	2.11	52.6	1923	10,974	0.7	0.5	0.4	0.5	7.0	16.3	24.5	22.3	16.5	6.8	2.6	1.9	Gravel
No. 2	6,381	5,000	2.41	3.88	.45	2.24	51.8	1923	11,205	1.4	1.2	1.2	1.0	8.1	16.7	20.0	21.3	16.5	7.3	2.9	2.4	Do
No. 3	2,634	2,200	2.42	3.84	.45	2.24	52.2	1923	4,937	2.4	1.9	1.6	1.7	7.2	14.6	17.6	21.9	18.1	7.5	3.0	2.5	Do
No. 4	9,674	6,500	2.43	4.25	.45	2.45	52.1	1923	15,944	2.9	2.3	2.4	2.3	9.8	16.2	18.4	17.3	13.7	7.3	3.9	3.5	Do
No. 5	967	600	2.22	4.23	.45	2.12	45.3	1923	1,273	0.9	0.7	0.4	0.5	9.3	21.2	23.6	21.1	12.8	6.4	1.9	1.2	Gravel and sand
No. 6	1,568	800	1.83	4.02	.45	1.93	43.2	1923	1,540	0.0	0.0	0.0	0.0	11.6	23.2	26.2	20.4	13.8	4.5	0.2	0.1	Sandy clay
No. 7	16,300	8,360	2.02	4.04	.45	2.22	49.5	1923	18,515	0.8	0.6	0.7	0.6	10.5	19.5	22.2	20.0	15.0	6.0	2.3	1.8	Quicksand, sandrock and shale
No. 8	2,443	1,000	3.72	6.68	.45	1.84	25.8	1923	1,840	0.1	0.1	0.1	0.2	11.5	20.0	22.1	19.3	16.2	7.6	1.5	1.3	Varies
No. 9	1,650	800	2.32	4.51	.45	1.64	33.1	1923	1,309	0.1	0.1	0.1	0.1	11.7	21.0	25.1	22.4	14.5	4.2	0.4	0.3	Clay

Table 5.-Maximum yield of drainage systems serving irrigated lands.

Location and name	Tributary area: Total	Tributary area: Irrigated	Length of drains: Open	Length of drains: Closed	Length of drains: Total	Average depth of drains	Maximum recorded discharge of drains: Date of record	Total	Per square mile of area	Per mile of drain	Maximum average monthly rate of discharge of drains: Date of record	Total	Per square mile of area	Per mile of drain	Predominating subsoil
	Sq. Mi.	Sq. Mi.	Miles	Miles	Miles	Feet		Sec. ft.	Sec. ft.	Sec. ft.		Sec. ft.	Sec. ft.	Sec. ft.	
ARIZONA															
Salt River Project (1)	385.00	360.47									Aug. 1925	555.6	1.54		Caliche, clay, gravel.
Yuma Project, Valley Division	65.00	64.26	37.3		37.3	9.0	June 1924	122.0	1.90	3.28	June 1924	94.4	1.47	2.63	Fine sand
CALIFORNIA															
Yuma Project, Reservation Div.	17.05	12.34			10.0	9.0	May 1924	30.0	2.43	3.00	May 1924	27.8	2.25	2.78	Fine sand.
Palo Verde Irrigation District.	114.06	52.03	51.5		51.5		June 1923	300.0	5.77	5.83	June 1923	265.5	5.10	5.16	Sand
" " " East Side Drain, Sta.1			6.5		6.5		June 1924	34.6		5.32					"
" " " " " " Sta.1-A			10.7		10.7		May 1924	61.3		5.73					"
" " " Levee Borrow Pit, Sta.2			16.0		16.0		June 1923	159.0		9.94					"
" " " Township Drain, Sta.3			33.0		33.0		June 1923	231.3		7.01					"
" " " Levee Borrow Pit. Sta.3-A			10.0		10.0		June 1923	103.0		10.30					"
Kearney Vineyard Exp. Drain.				4.14	4.14	5.7	April 1915	2.38		.57					Hardpan.
Baker Tract				.56	.56		April 1908	.24		.43					Silt, quicksand, hardpan.
Dore Tract				.85	.85		Mar. 1908	.65		.76					" " "
Modesto Irrigation District. (2)	75.0	59.38									June 1927	102.3	1.72		Hardpan and sand.
Merced Irrigation District (1)	117.19	70.31									Aug. 1927	147.8	2.10		" " "
Turlock Irrigation District (2)	283.58	203.13									Sept. 1927	205.0	1.01		" " "
COLORADO															
Prowers Co., Granada Drainage District	12.50	10.94	11.0		11.0						June 1926	28.0	2.56	2.55	Varies.
" " Holly D.D.	15.63	14.06	11.5		11.5						June 1926	63.3	4.50	5.50	Varies
San Luis Valley, Carmel D.D.	8.97	6.25	18.75	.45	19.2	6.7	July 1917	26.2	4.19	1.36	July 1917	24.7	3.95	1.29	Coarse sand and gravel.
" " " Rio Grande D.D.	53.13				45.5	5.5	June 1920	79.9	3.41	1.76	June 1920	70.0	2.99	1.54	" " " "
Logan Co., Prewitt Drain			3.0		3.0						June 1920	57.4		19.13	" " " "
Morgan Co., Bijou Drain			2.5		2.5						Aug. 1920	14.6		5.84	Coarse sand.
" " Shumacher Drain			2.5		2.5						Aug. 1920	13.16		5.26	Sand.
Weld Co., Day and Smiley Drain			3.0		3.0						May 1920	20.8		6.93	Medium to coarse sand.
Farm near Grand Junction				.19	.19	6.0	July 1914	.20		1.05	July 1914	.18		.95	Shale
Canon City				.07	.07	7.0	July 1915	.05		.71					"
" "				.07	.07	7.0	July 1915	.08		1.14					"
IDAHO															
Ada Co., D.D.No. 2	48.44	43.75	40.65	1.74	42.39	10.2					June 1923	294.1	6.72	6.94	Gravel and sand.
" " " " Eagle Drain	7.81	7.03	6.78		6.78	10.2	June 1922	65.0	9.24	9.59	July 1925	48.6	6.91	7.17	" " "
" " " " Collister Drain	1.25	1.17		1.74	1.74	9.0	Sept. 1922	10.0	8.55	5.75	Sept. 1922	9.6	8.21	5.52	" " "
" " " " Hartley Drain	2.81	2.58	3.37		3.37	10.2	Sept. 1923	30.0	11.65	8.90	Sept. 1923	21.1	8.18	6.26	" " "
" " " " No. 9 outlet	34.57	32.97	30.50		30.50	10.2	June 1924	276.0	8.37	9.05	June 1923	247.9	7.52	8.12	" " "
Ada Co., D.D.No. 3	6.56	6.09			5.86	7.8	July 1925	22.0	3.61	3.75	July 1925	20.5	3.37	3.50	" " "
Ada Co., D.D.No. 4	4.00	3.50	7.27		7.27	6.4	July 1925	27.0	7.71	3.71	July 1925	23.5	6.64	3.20	" " "
Blaine Co., D.D.No. 1	2.70		5.2		5.2	7.0	July 1921	13.6		2.52	July 1921	10.6		2.04	Gravel, cemented in places.
Franklin Co., D.D.No. 3, Main Drain.	4.67	3.50			58.0	5.0	Apr. 1925	1.50	.43	.04					
" " " " X Drain	.65	.50		6.20	6.20	5.0	May 1925	.18	.36	.03					Clay with thin layer of sand.
Canyon Co., D.D.No.1	16.25		17.0		17.0	6+	Oct. 1923	107.0		6.30	Sept. 1923	84.7		4.98	Gravel, some clay and sandy loam.
Canyon Co., D.D.No. 2, Drain C	.64	.61		.92	.92	10.0	Sept. 1923	1.32	2.16	1.43					Sand and gravel.
Minidoka Project.	62.50	45.30	90.0		90.0	9.0					Aug. 1916	226.0	5.02	2.51	Sand.
" " Drain D-3	3.60	2.69	6.0		6.0						Aug. 1918	20.4	7.58	3.40	"
" " Drain D-4	5.50	4.13	9.0		9.0						Aug. 1919	27.7	6.71	3.08	"
" " Drain D-5	3.60	2.75	8.5		8.5						June 1919	8.7	3.16	1.02	Sand and hardpan.
" " Drain D-6-15-16	11.00	8.25	23.0		23.0						Aug. 1918	36.2	4.39	1.57	Sandy.
" " Drain D-13	.60	.45	.8		.8						Aug. 1917	2.0	4.44	1.50	"
" " Drain D-12	6.30	4.72	9.0		9.0						July 1916	40.2	8.52	4.47	Coarse sand.
" " Main Drain	31.00	23.20	32.5		32.5						Aug. 1916	102.8	4.43	3.16	Sand.
Payette Co., D.D.No. 1	1.87	1.72			4.9	7.8	July 1923	10.9	6.30	2.23	Aug. 1923	10.0	5.82	2.04	Sand and gravel.
Pioneer Nampa-Meridian Dist.	238.80	210.94	131.4		131.4	9-10					June 1920	549.2	2.60	4.18	Coarse sand, [illegible] and gravel.
" " " Dixie and West End drains.	23.40	20.94	13.5		13.5						June 1920	73.8	3.52	5.47	Sand and gravel
" " " Wilson Cr. System	58.30	46.09	32.3		32.3						July 1920	162.4	3.52	5.03	Coarse sand and gravel.
" " " Indian Cr. System	32.60	29.38	20.7		20.7						June 1920	79.0	2.69	3.82	Sand and clay.
" " " Mason Cr. System	65.80	59.84	33.3		33.3						June 1920	166.2	2.78	4.99	Gravel and sand.
" " " Five Mile System	58.70	54.69	31.6		31.6						July 1920	88.4	1.62	2.80	Gravel and sand, compact.
" " " Upper Embk. Drain	1.95		1.3		1.3						July 1917	14.1		10.85	Gravel and sand.
Tucker Tract near Notus.				.62	.62	6.5	June 1913	1.08		1.74	July 1914	.46		.74	Sandy loam hardpan.
Boise Project, Lower Division.															
" " " " Fargo Basin.	8.75	7.81	5.60	.20	5.80						July 1920	25.2	2.97	4.00	Sand and gravel.
" " " " Dotson Drain	5.25	4.95	6.85		6.85		July 1925	24.4	5.14	3.56					
" " " " East End Drain.			3.6		3.6	10.0	July 1919	10.2		2.83	Aug. 1920	7.84		2.18	
" " " " East Alkali Drain	5.34	3.91	5.65		5.65		Sept. 1920	16.1	4.12	2.85	Sept. 1920	15.6	3.99	2.76	
" " " " Egger Drain			.56		.56		July 1919	3.3		5.90					Gravel
" " " " Idemiller Drain			.80		.80		Sept. 1921	2.15		2.69					
" " " " Griffith Drain	.81	.78	1.45		1.45		Aug. 1921	7.82	10.03	5.39	Aug. 1921	7.79	9.99	5.37	Sand and gravel
" " " " Graber Drain	.31	.30	.70		.70		Sept. 1921	.63	2.10	.90	Aug. 1921	.56	1.87	.80	
" " " " Lowell Drain	1.00	.90	1.54		1.54	12.0	July 1919	9.0	10.00	5.84					Gravel and coarse sand.
" " " " Laht Drain	6.88	6.25	4.20		4.20		Aug. 1921	26.55	4.25	6.32	Aug. 1921	17.30	2.77	4.12	sand and gravel.
" " " " Lower Embk. Drain	3.80	2.97	4.80		4.80		June 1920	15.3	5.15	3.19	July 1921	13.3	4.48	2.77	
" " " " Ross System	4.69	4.38	6.80		6.80	8.2	Sept. 1920	34.8	7.95	5.12	Aug. 1921	34.6	7.90	5.09	Gravel
" " " " Roswell Drain			.59		.59		July 1919	1.90		3.22					
" " " " Sterry Drain			1.06		1.06	8.7	July 1919	5.40		5.09					Gravel
" " " " Scott Drain.	1.72	1.09	2.50		2.50		July 1920	7.93	7.28	3.17	July 1920	7.84	7.19	3.14	
IDAHO-OREGON															
Boise Project, Lower Div., Allen Drain	1.46	1.38	2.50		2.50	10	Sept. 1920	11.80	8.55	4.72	Sept. 1920	9.30	6.74	3.72	Gravel
" " " " Central Alkali Drain	1.50	1.10	3.00		3.00		July 1920	10.50	9.54	3.50					
" " " " Riverside System	31.25	25.42	40.70		40.70	10.0					Sept. 1920	105.7	4.16	2.60	Gravel, sand and shale.
OREGON															
Boise Project, Lower Div., Singer System	3.13	2.81	7.6		7.6						Aug. 1920	7.32	2.61	.95	Shale
" " " " S. Alkali Drain.	3.26	2.97	5.4		5.4		Sept. 1920	17.5	5.99	3.30	Oct. 1920	14.77	4.97	2.74	
" " " " Welch Drain	.78	.69	2.25		2.25	9.4					Sept. 1920	2.30	3.33	1.02	Fine sand, silt and clay.

(1) Drainage water all pumped from wells.
(2) Drainage yield includes water pumped from wells and discharge from gravity drains.

Table 4.-Maximum yield of drainage systems serving irrigated lands - Con.

Location and name	Tributary area: Total	Tributary area: Irrigated	Length of drains: Open	Length of drains: Closed	Length of drains: Total	Average depth of drains	Maximum recorded discharge of drains: Date of record	Maximum recorded discharge of drains: Total	Maximum recorded discharge of drains: Per square mile of area	Maximum recorded discharge of drains: Per mile of drain	Maximum average monthly rate of discharge of drains: Date of record	Maximum average monthly rate of discharge of drains: Total	Maximum average monthly rate of discharge of drains: Per square mile of area	Maximum average monthly rate of discharge of drains: Per mile of drain	Predominating subsoil
OREGON	Sq. Mi.	Sq. Mi.	Miles	Miles	Miles	Feet		Sec.ft.	Sec.ft.	Sec.ft.		Sec. ft.	Sec.ft.	Sec.ft.	
Klamath Project	44.22	36.25			75.0	7.0					Aug. 1925	80.0	2.21	1.07	Hardpan, chalk and fine sand.
Nyssa Arcadia Drainage District	11.40	8.17	14.31		14.31	9.0					July 1923	26.4	3.23	1.84	Fine sand under hardpan.
Umatilla Drainage District	5.94	5.65			4.5	4-9					June 1923	17.5	3.11	3.89	Gravel and sand.
Umatilla Project, Main Drain	19.0	7.03	5.62		5.62	5-20	Aug. 1925	81.0	11.52	14.41	Aug. 1925	79.5	11.31	14.15	Sand and gravel.
" " " "			1.00		1.00	18.0	Aug. 1922	42.0		42.0					Gravel and sand.
UTAH															
Benjamin D.D., Drain D-20	1.08	.92		4.49	4.49		July 1922	2.88	3.15	.64					Sand
" " " Drain B	2.00	1.70		6.48	6.48		July 1923	4.50	2.65	.53					"
" " " Drain E	.25			1.12	1.12		Aug. 1922	1.09	* 4.36	.97					"
" " " Drain A-50	1.81			8.43	8.43		July 1922	4.17	* 2.30	.49					"
Brighton D.D., Drain A	.74				4.42		July 1924	.59	* .80	.13					Clay
Davis Co., D.D.No.1, Drain A-16	.90				7.50		July 1924	.98	* 1.09	.13					"
Elwood D.D., Drain Bw	.09				.88		July 1923	.14	* 1.55	.16					Clay loam
" " " Drain Be	.30				2.92		July 1924	.60	* 2.00	.21					" "
" " " Drain D	.47				4.49		July 1924	.83	* 1.77	.18					" "
" " " Drain I	.48				4.72		July 1923	.60	* 1.25	.13					" "
" " " Drain J	.39				3.35		July 1923	.32	* .82	.10					" "
" " " Drain A	.26				2.39		July 1924	.14	* .54	.06					" "
Jensen Tract				.19	.19	4.0	1910	1.25		6.58					Gravel
Lake Shore and Benjamin D.D., Drain A-60	.79		4.02		4.02	6.5	June 1924	1.25	* 1.58	.31					Clay and sand.
" " " " " " Main	4.84		7.38	13.17	20.50		Aug. 1922	9.61	* 1.99	.47					Sandy clay and sand.
Lake Shore and North D.D., Drain A-20	.64			2.80	2.80		July 1922	.90	* 1.41	.32					Clay and sand.
Millard Co., D.D.No.1, Main	8.26						July 1923	5.44	* .66						
Millard Co. D.D.No.2, Drain B	2.47				13.8		July 1923	3.06	* 1.24	.22					
" " " " " " Drain C	1.25	.85			8.82		July 1924	2.40	2.82	.27					Clay and sand.
" " " " " " Drain E	2.44				20.33		July 1923	1.24	* .51	.06					" " "
" " " " " " Drain E-20	1.56				12.50		July 1923	1.05	* .67	.08					" " "
" " " " " " Drain F	2.49	.83			16.60		July 1923	2.87	3.46	.17					Sandy clay and clay
" " " " " " Drain D-100	1.18				8.44		July 1924	.85	* .72	.10					" " " "
" " " " " " Drain D-40	1.17				6.08		July 1924	.36	* .31	.06					" " " "
" " " " " " Drain A-20	3.10				17.0		July 1924	1.70	* .55	.10					
Millard Co., D.D.No.3, Drain B	.52				2.71		July 1923	.87	** 1.67	.32					Clay and clay loam.
" " " " " " Drain B-80	1.09				8.01		July 1923	1.06	* .97	.13					" " " "
" " " " " " Drain B-100	4.59	2.76		35.30	35.30		July 1923	5.59	2.03	.16					" " " "
" " " " " " Drain B-620	.52				2.90		July 1924	.56	* 1.08	.20					" " " "
" " " " " " Drain C-500	2.77				15.15		July 1923	.765		.05					
" " " " " " Drain C-50	.85				4.03		July 1924	.41	* .48	.10					
" " " " " " Drain C	4.54	3.59			26.60		July 1924	3.40	.95	.13					Clay and clay loam.
" " " " " " Drain D-500	.90				9.40		Aug. 1923	3.45	* 3.83	.37					Sandy.
" " " " " " Drain E	5.02	3.01		36.50	36.50		July 1923	2.69	.89	.07					Clay and sand.
" " " " " " Drain E-170	.72				5.06		July 1923	.26		.05					
" " " " " " Drain E-100	2.48				14.68		July 1924	.81		.06					
Millard Co., D.D.No.4, Drain A	2.02	.90			12.97		Aug. 1924	1.40	1.56	.11					Clay, sandy clay and sand.
" " " " " " Drain A-120	.53	.28			5.26		July 1923	.39	1.39	.07					" " " " "
" " " " " " Drain A-426	.60				4.13		July 1924	.32		.08					" " " " "
" " " " " " Drain A-400	.34				2.38		July 1924	.16		.07					" " " " "
Redmond D.D. I	.34			3.57	3.57		Aug. 1924	1.50	* 4.41	.42					Varies from
" " " II	.55			6.00	6.00		July 1923	1.90	* 2.92	.32					sand to
" " " VIII	.05				.60		Aug. 1923	.15	* 3.00	.25					clay
San Pete Co., D.D.No.1, Main	.85		.76	6.70	7.46		Aug. 1922	13.2		1.77					Varies
" " " " " " Drain No.7	.05			.38	.38		Aug. 1922	.43		1.13					from
" " " " " " D.E.L.	.05			.30	.30		Aug. 1922	.16		.53					
" " " " " " No.Main	.33			2.63	2.63		Aug. 1922	3.02		1.15					
" " " " " " Drain 4b	.09			.52	.52		Aug. 1922	1.25		2.40					gravel
" " " " " " Drain 4	.18			1.88	1.88		Aug. 1922	.84		.45					to
" " " " " " Drain 3	.07			.49	.49		Aug. 1922	.44		.90					
" " " " " " Drain 2	.06			.49	.49		Aug. 1922	.17		.35					clay
" " " " " " Kearn's So.Main	.34			2.84	2.84		Aug. 1922	1.18		.42					
" " " " " " Mellor Main	.66			5.18	5.18		Aug. 1923	7.4		1.43					
" " " " " " Kearn's No.Main	.20			1.64	1.64		Aug. 1922	.70		.43					
" " " " " " Nielson's No.Main	.28			2.29	2.29		Aug. 1922	.45		.20					
Sevier Co., D.D.No.2, Drain 30 and 30x	1.88	1.75		6.95	6.95		Aug. 1923	6.74	3.85	.97					Sand and gravel
" " " " " Drain 50	1.08	1.00		5.60	5.60		July 1922	3.68	3.68	.66					" " "
Sevier Co., D.D.No.3, Drain B	.32			1.25	1.25		July 1923	1.82		1.46					" " "
" " " " " Drain E	.62			2.55	2.55		July 1922	3.60		1.41					" " "
" " " " " Drain D	.26			1.21	1.21		July 1923	2.14		1.77					" " "
Sevier Co., D.D.No.4 I	.26			3.28	3.28		Sept. 1924	1.01		.31					
" " " " " II	.44			4.12	4.12		Aug. 1923	.50		.12					
" " " " " IV	.13			.93	.93		Aug. 1923	.25		.27					
Sevier Co., D.D.No.5, Main	2.08	1.63		18.70	18.70		July 1922	3.50	2.16	.19					Clay and some fine sand.
Sevier Co., D.D.No.6, No.Main	.06			.91	.91		July 1923	.22		.24					Varies from
" " " " " So.Main	.46			4.44	4.44		Aug. 1922	1.90		.43					clay to fine sand
" " " " " Half Moon	.23			2.72	2.72		July 1923	1.12		.41					and a little gravel
Swan Tract				2.13	2.13	4.0					Sept. 1903	.27		.15	Clay, hardpan and sand.
Utah Co., D.D.No.1, Drain B	1.08			6.24	6.24		July 1922	4.13		.66					Sandy clay.
Webb Tract				.22	.22	5.0	June 1913	.53		2.41					Sand and gravel.

* Discharge per square mile based on total area rather than on irrigated area as in all other cases.

Table 4.-Maximum yield of drainage systems serving irrigated lands - Con.

Location and name	Tributary area: Total	Tributary area: Irrigated	Length of drains: Open	Length of drains: Closed	Length of drains: Total	Average depth of drains	Maximum recorded discharge of drains: Date of record	Maximum recorded discharge of drains: Total	Maximum recorded discharge of drains: Per square mile of area	Maximum recorded discharge of drains: Per mile of drain	Maximum average monthly rate of discharge of drains: Date of record	Maximum average monthly rate of discharge of drains: Total	Maximum average monthly rate of discharge of drains: Per square mile of area	Maximum average monthly rate of discharge of drains: Per mile of drain	Predominating subsoil
	Sq. Mi.	Sq. Mi.	Miles	Miles	Miles	Feet		Sec.ft.	Sec.ft.	Sec.ft.		Sec. ft.	Sec.ft.	Sec.ft.	
MONTANA															
Huntley Project.	18.13	10.65		29.82	29.82	8-9	Sept. 1925	17.80	1.69	.60					Clay, sand and gravel.
" "	14.53	8.59		26.07	26.07						Aug. 1915	12.40	1.44	.48	" " " "
" " Drains 1 and 14 (3)	.31			1.66	1.66		Sept. 1925	.99		.60					
" " Drain 2	.37			1.04	1.04		Aug. 1915	1.16		1.12	Aug. 1915	1.05		1.01	
" " Drain 4	.04			.06	.06						June 1915	.09		1.50	
" " Drains 5 and 5-1	1.01			2.65	2.65		Sept. 1925	1.28		.48	Aug. 1915	1.08		.41	
" " Drain 6	2.81			3.60	3.60		Sept. 1925	2.93		.81	Aug. 1915	1.94		.54	
" " Drain 7	1.05			2.20	2.20		Sept. 1914	2.00		.91	Aug. 1915	1.11		.50	
" " Drain 8	.41			1.16	1.16		Aug. 1915	.80		.69	Aug. 1915	.57		.49	
" " Drain 9	.93			2.55	2.55		July 1914	1.60		.63	Aug. 1915	.89		.35	
" " Drain 10	3.59			4.76	4.76		Sept. 1925	2.09		.44	Sept. 1915	1.87		.39	
" " Drain 11	1.35			2.18	2.18		Sept. 1915	1.23		.56	Sept. 1915	1.11		.51	
" " Drains 12 and 12-1	.66			1.86	1.86		Nov. 1915	1.43		.77	Nov. 1915	1.33		.72	
" " Drain 13	5.30			6.09	6.09		Sept. 1925	4.35		.71					
" " Drain 14	.51			1.17	1.17		Aug. 1915	.72		.62	May 1915	.69		.59	
" " Drain 17	2.01			2.84	2.84		Sept. 1915	1.84		.65	Sept. 1915	1.81		.64	
" " Drain 20	1.47			2.21	2.21		Sept. 1925	.64		.29					
" " Drain 24	.39			.95	.95		Sept. 1925	.64		.67					
" " Drain 25	.64			1.05	1.05		Sept. 1925	1.58		1.50					
" " Drain 32	.21			.95	.95		Sept. 1925	.19		.20					
Lower Yellowstone Project			4.5	1.1	5.6	8.0	Aug. 1918	9.5		1.70					Gravel
" " "				1.1	1.1		1926	2.0		1.82					"
NEBRASKA															
Lincoln Co., D.D.No. 1	17.30	10.	22.0	6.0	28.0	9-10	Aug. 1926	114.5	11.45	4.09	Aug. 1926	108.1	10.81	3.86	Coarse sand, some gravel.
North Platte Project., Interstate Div.	124.06	79.69			46.0	8.0	Sept. 1925	294.3	3.69	6.40	Sept. 1925	287.5	3.61	6.25	Fine sand, gravel and Brule clay.
" " " " Sheep Cr.	43.75	25.63			14.5	8.0	Oct. 1925	107.9	4.21	7.44	Oct. 1925	102.8	4.01	7.09	Varies.
" " " " Dry Spotted Tail	26.41	22.50			8.5	6.0	Sept. 1925	77.9	3.46	9.16	Sept. 1925	66.2	2.94	7.79	Fine sand and gravel.
" " " " Tub Springs	11.56	7.34			6.5		Sept. 1925	32.2	4.39	4.95	Sept. 1925	31.4	4.28	4.83	
" " " " Dunham-Andrews	11.56	6.25			5.5	7.0	Aug. 1925	15.7	2.51	2.85	Aug. 1925	14.3	2.29	2.60	Fine sand and Brule clay.
" " " " Winters Cr.	17.50	10.16			6.5	9.0	Aug. 1925	69.7	6.86	10.72	Aug. 1925	57.2	5.63	8.80	Fine sand and gravel.
" " " " Alliance	13.28	7.81			4.5		Aug. 1925	29.6	3.79	6.58	Aug. 1925	27.0	3.46	6.00	
" " " Minatare and L.Nine Mile	80.0				30.0		Sept. 1925	236.3		7.88	Sept. 1925	223.2		7.44	
" " " Northport Div., Indian Cr.	10.94				4.9		Sept. 1925	50.5		10.31	Sept. 1925	37.4		7.63	
" " " " " Silver Nail	7.05				2.5		Aug. 1925	14.6		5.84	Aug. 1925	12.2		4.88	
WYOMING															
North Platte Project, Ft. Laramie Div.	70.0	28.12			56.7		Aug. 1925	102.9	3.66	1.81	Aug. 1925	73.6	2.62	1.30	Tight formation.
" " " " " Cherry Cr.	37.0	14.84			33.0		Aug. 1925	59.5	4.01	1.80	Aug. 1925	41.2	2.78	1.25	
" " " " " Pullen Dr.	3.0	1.56			2.7		July 1925	3.9	2.50	1.44	July 1925	2.33	1.49	.86	
" " " " " Katzer Dr.	30.0	11.72			21.0		Aug. 1925	40.5	3.46	1.93	Aug. 1925	30.9	2.64	1.47	
NEVADA															
Newlands Project.	150.0	70.14	148.73		148.73	8.7					Aug. 1923	204.2	2.91	1.37	
" " N.Carson Div.	10.0	5.15	8.42		8.42						Aug. 1923	20.9	4.06	2.48	Sandy
" " " " Lower Soda Lake Dr.			3.28		3.28						July 1923	4.2		1.28	Sandy
" " " " Upper Soda Lake Dr.			3.14		3.14						June 1923	7.0		2.23	Sandy
" " " " S.Upper Soda Lake Dr.			1.00		1.00						Aug. 1923	2.0		2.00	Sandy
" " S.Carson Div.	125.0	55.98	131.9		131.9						June 1923	157.1	2.81	1.19	
" " " " Carson Lake Dr.			11.42		11.42						July 1923	22.53		1.97	Heavy clay.
" " " " Harmon Dr.			15.38		15.38						July 1923	18.8		1.22	Sandy loam
" " " " Kent Lake Dr.			3.03		3.03						June 1923	8.06		2.66	Heavy clay.
" " " " L Drain			4.48		4.48						Aug. 1923	24.39		5.44	Sand
" " " " New River Dr.			7.10		7.10						Aug. 1923	18.59		2.63	Sandy
" " Truckee Div.	15.0	9.01	8.41		8.41						Aug. 1923	54.5	3.83	4.10	
" " " " Fernley Dr.			7.54		7.54						July 1923	31.5		4.18	Sandy
" " " " Hazen Dr.			.87		.87						Sept. 1923	3.50		4.02	Sandy loam and gravel
Truckee Carson Experiment Farm				.50	.50	4.7					May 1913	.56		1.12	
NEW MEXICO															
Carlsbad Project	7.86	6.25	11.14	3.65	14.79	9.0					1919	17.0	2.72	1.15	Gypsum, sand and gravel
NEW MEXICO-TEXAS															
Rio Grande Project	266.0	204.55	352.5		352.5						July 1925	613.4	3.00	1.74	Fine sand.
" " " Mesilla Div.	148.0	105.24	177.5		177.5	10.0					July 1925	390.3	3.71	2.20	Fine sand.
" " " " " Anthony Drain	7.0		8.0		8.0		Aug. 1924	18.3		2.29	Aug. 1924	13.8		1.73	
" " " " " Chamberino Drain	4.0		5.4		5.4		Aug. 1924	12.2		2.26	July 1925	9.90		1.83	
" " " " " Del Rio Drain	28.0		31.9		31.9		July 1925	106.1		3.33	July 1925	102.0		3.20	
" " " " " East Drain	16.0		19.2		19.2		July 1925	40.0		2.08	July 1925	36.2		1.89	
" " " " " La Mesa Drain	10.0		16.8		16.8		July 1925	41.9		2.49	July 1925	39.8		2.37	
" " " " " Leasburg Drain.	8.0		11.3		11.3						June 1923	32.9		2.91	
" " " " " Mesilla Drain	16.0		17.3		17.3						June 1923	26.7		1.54	
" " " " " Montoya Drain	7.0		8.2		8.2		Apr. 1925	16.1		1.96	Apr. 1925	15.0		1.83	
" " " " " Nemexas Drain	19.0		19.3		19.3		Oct. 1925	38.8		2.01	Apr. 1925	36.5		1.89	
" " " " " Picacho Drain	6.0		7.2		7.2		July 1925	16.5		2.29	July 1925	14.6		2.03	
" " " " " Selden Drain	4.0		4.6		4.6		June 1925	12.5		2.72	June 1925	11.3		2.46	
" " " " " West Drain	23.0		28.3		28.3		June 1925	89.7		3.17	June 1925	72.9		2.58	
NEW MEXICO															
Rio Grande Project, Rincon Div.	20.0	14.60	28.7		28.7	10.0					Aug. 1925	55.0	3.77	1.92	Fine sand
" " " " Garfield Drain	10.0		14.2		14.2		May 1925	28.3		1.99	May 1923	28.3		1.99	
" " " " Hatch Drain	6.0		10.2		10.2		Aug. 1925	30.3		2.97	Aug. 1925	25.1		2.46	
" " " " Rincon Drain	4.0		6.3		6.3		Dec. 1925	13.3		2.11	Dec. 1925	11.2		1.78	
TEXAS															
Rio Grande Project, El Paso Div.	96.0	84.75	147.8		147.8	10.0					May 1925	177.4	2.09	1.20	Fine sand.
" " " " " "	98.0	74.48	118.0		118.0						May 1924	188.6	2.53	1.60	
" " " " " Alamo Drain	5.0		7.9		7.9		June 1925	17.8		2.25	June 1925	16.4		2.08	
" " " " " Border Drain	5.0		7.2		7.2		June 1925	10.0		1.39	June 1925	8.8		1.22	
" " " " " Fabens Drain	4.0		6.8		6.8		Aug. 1925	26.3		3.87	June 1924	22.0		3.23	
" " " " " Franklin and Playa Drs.	14.6		15.9		15.9		July 1925	30.4		1.91	May 1924	28.3		1.78	
" " " " " Island Drain	10.0		13.3		13.3		May 1925	30.3		2.28	May 1925	22.1		1.66	
" " " " " Mesa Drain	20.0		21.9		21.9		Apr. 1925	54.7		2.50	Apr. 1925	38.4		1.75	
" " " " " Middle, Franklin and Playa Drs.	33.0		33.8		33.8		July 1925	64.5		1.91	July 1925	52.5		1.55	
" " " " " Playa Drain	5.0		6.7		6.7		May 1924	21.6		3.22	May 1924	19.5		2.91	
" " " " " River Drain	11.0		15.3		15.3		May 1924	30.9		2.02	May 1924	26.3		1.72	
" " " " " Tornillo Dr.	15.0		18.4		18.4		May 1924	41.9		2.28	May 1924	35.1		1.91	

(3) For the Huntley Project data were available only on one set of measurements for 1925 andthese are given when they exceed in amount any previous records.

Table 4.-Maximum yield of drainage systems serving irrigated lands - Con.

Location and name	Tributary area: Total area	Tributary area: Irrigated area	Length of drains: Open	Length of drains: Closed	Length of drains: Total	Average depth of drains	Maximum recorded discharge of drains: Date of record	Maximum recorded discharge of drains: Total	Maximum recorded discharge of drains: Per square mile of area	Maximum recorded discharge of drains: Per mile of drain	Maximum average monthly rate of discharge of drains: Date of record	Maximum average monthly rate of discharge of drains: Total	Maximum average monthly rate of discharge of drains: Per square mile of area	Maximum average monthly rate of discharge of drains: Per mile of drain	Predominating subsoil
	Sq. mi.	Sq. mi.	Miles	Miles	Miles	Feet		Sec.ft.	Sec.ft.	Sec.ft.		Sec.ft.	Sec.ft.	Sec.ft.	
WASHINGTON															
Yakima County drainage districts, total	115.63	110.59			215.84						Sept. 1923	232.2	2.10	1.08	
" " Yakima Project, Sunnyside Div., Total	94.22	90.33			176.85						Sept. 1923	160.0	1.77	.90	
" " Tributary to Sulphur Cr.W.W.	45.63	43.66			90.0						Sept. 1925	82.4	1.89	.92	Hardpan with sand pockets.
" " D.D.No.Joint 1	3.60	3.40		3.89	3.89	7.5	July 1925	3.00	.88	.77	July 1925	2.82	.83	.73	Lava rock.
" " " " No.2	16.56	16.13	13.45	15.82	29.27	7.8	May 1925	36.60	2.27	1.25	May 1925	28.50	1.77	.97	Hardpan and sand.
" " " " No.3, Main	17.03	15.88	14.04	13.90	27.94		May 1925	22.80	1.44	.82					Hardpan with sand pockets.
" " " " No.3,Sub.6 and Lat.C,Sub.5	3.75	3.58	2.88	1.84	4.72		July 1923	6.00	1.68	1.27	June 1923	5.65	1.58	1.20	
" " " " No.3,,Lat.C,Sub.5			2.88		2.88		July 1925	4.42		1.53					Hardpan
" " " " No.3, Sub.6,Main				1.39	1.39		Aug. 1923	1.75		1.24					Sandy.
" " " " No.3,Sub. 6,Lat.A				.45	.45		Apr. 1924	.52		1.16					Sandy.
" " " " No.4	2.50	2.36		7.65	7.65		Oct. 1922	7.33	3.11	.96	July 1923	6.50	2.76	.85	Sandy loam and gravel.
" " " " No.5	3.52	3.29	3.76	.54	4.30	7.0	May 1925	8.53	2.59	1.98					Hardpan.
" " " " No.7	6.02	5.65	5.89	2.30	8.19	11.3	Oct. 1923	30.45	5.39	3.72	Oct. 1923	29.60	5.24	3.61	Sand,little hardpan.
" " " " No.7,Sub.1		1.10	.24	2.30	2.54	8.0	Sept. 1923	2.23	2.03	.88	Sept. 1923	2.15	1.95	.85	Clay loam.
" " " " No.9,Main	12.73	12.45	15.21	18.09	33.30	7.9	May 1925	28.00	2.25	.84					Hardpan and sand pockets.
" " " " No.9,Sub.F	1.85	1.77		8.44	8.44	9.3	Aug. 1925	3.99	2.25	.47	Aug. 1925	3.98	2.25	.47	
" " " " " " " " Lat.A		.90		4.31	4.31		Aug. 1925	2.12	2.36	.49					Hardpan and sand pockets.
" " " " " " " " Lat.K		.29		1.50	1.50		May 1924	1.04	3.59	.69					Hardpan and sand.
" " " " " " " " Lat.G		.18		.95	.95		July 1925	.71	3.94	.75					Sandy.
" " " " " " " " Lat.B		.40		1.68	1.68		Aug. 1923	.87	2.18	.52					Hardpan.
" " " " No.10	3.67	3.58	1.24	3.86	5.10		Aug. 1925	8.98	2.51	1.76	Aug. 1925	8.58	2.40	1.68	Hardpan and sand pockets.
" " " " No.12,Main	2.58	2.46	4.04		4.04	6.0	Sept. 1923	15.42	6.27	3.82	Sept. 1923	14.80	6.02	3.66	Sand and hardpan.
" " " " No.12,E.Br.		.34	.91		.91		Oct. 1914	2.35	6.91	2.48					Sand.
" " " " No.13			.51	3.83	4.34	3.5	May 1924	16.20		3.73	June 1924	13.20		3.04	Gravel
" " " " No.15	1.25	1.21	1.21	3.15	4.36	5.0	Oct. 1925	1.05	.87	.24	Sept. 1925	1.02	.84	.23	Silt.
" " " " No.16	1.14	1.09	1.70	.34	2.04		Sept. 1923	1.80	1.65	.88	Sept. 1923	1.60	1.47	.78	Silt.
" " " " No.17	1.03	.98	1.93	.52	2.45	5.2	May 1914	3.00	3.06	1.22	Sept. 1923	2.75	2.81	1.12	Hardpan and sandy loam
" " " " No.18	1.41	1.35	1.94	1.11	3.05	7.0	May 1925	5.03	3.73	1.65					Sand and hardpan.
" " " " No.19	1.22	1.16	3.30	.39	3.69	5.6	Aug. 1925	3.00	2.59	.81	Sept. 1925	2.90	2.50	.79	Hardpan.
" " " " No.20	1.50	1.49	2.39	1.01	3.40	6.5	May 1925	4.60	3.09	1.35	June 1923	3.76	2.52	1.11	Hardpan.
" " " " No.24	1.80	1.71		2.23	2.23	7.8	Oct. 1922	11.60	6.78	5.20	Oct. 1922	11.00	6.43	4.93	Gravel and sand.
" " " " No.25	5.78	5.59	2.59	6.83	9.42	7.2	May 1925	8.30	1.48	.88	May 1921	6.70	1.20	.71	Hardpan and silt.
" " " " No.27	1.88	1.75		5.72	5.72	7.3	May 1926	3.90	2.23	.68					Hardpan.
" " " " No.28	.90	.83		1.60	1.60		Aug. 1923	10.70	12.89	6.69	Aug. 1923	8.85	10.66	5.53	Gravel
" " " " No.29	.78	.64		1.55	1.55		Sept. 1924	1.21	1.89	.78	Sept. 1924	1.13	1.77	.73	Hardpan.
" " " " No.31	2.89	2.78	.86	4.87	5.73	9.4	Sept. 1923	5.24	1.88	.91	Sept. 1923	4.96	1.78	.87	Hardpan, sand.
" " " " No.32	.81	.78		3.65	3.65		July 1925	1.73	2.22	.47	Sept. 1925	1.66	2.13	.45	Hardpan.
" " " " No.33	1.72	1.55	.10	2.44	2.54	7.4	June 1925	16.40	10.58	6.46	June 1925	16.10	10.39	6.34	Gravel.
" " " " No.35	2.42	2.26		5.44	5.44	8.0	Aug. 1922	4.73	2.09	.87	Aug. 1922	4.15	1.84	.76	
" " " " No.36,Main		1.49		4.42	4.42		Aug. 1922	3.30	2.21	.75					Silt
" " " " No.36,Lat.F		.77		1.02	1.02		Aug. 1925	1.90	2.47	1.86					Black sand.
" " " " No.38	1.56	1.47		5.00	5.00	4-8	May 1926	3.70	2.52	.74					Hardpan,cement gravel.
" " " " No.39		1.86		2.94	2.94		May 1924	13.80	7.42	4.69	June 1924	12.10	6.51	4.12	Gravel
" " " " No.40	1.05	1.03		2.33	2.33	3-9	May 1925	4.35	4.22	1.87					Hardpan,cement gravel.
" " " " No.41		1.97			3.44	2-8	May 1925	2.38	1.21	.69					Hardpan,cement gravel.
" " " " No.42				1.42	1.42	5.0	Aug. 1925	4.50		3.17					Gravel
Wapato Project	156.25	114.58	114.6		114.6	5-12					June 1925	830.0	7.24	7.24	Gravel
" "		70.0	48.0		42.0						June 1916	330.0	4.71	7.86	"
" " Drain No.1			3.8		3.8		July 1925	60.0		15.79	Aug. 1925	51.4		13.53	"
" " Drain No.2			10.2		10.2		May 1925	216.0		21.18	May 1925	213.0		20.88	"
" " Drain No.3			8.8		8.8		July 1925	228.0		25.91	June 1925	201.0		22.84	"
" " Drain No.4			10.5		10.5		July 1925	220.0		20.95	July 1925	191.0		18.19	"
" " E.Toppenish Drain.			3.2		3.2		Sept. 1925	48.0		15.00	May 1925	39.4		12.31	"
Yakima City West Side Drain				.73	.73	12-18	June 1912	20.77		28.45					Gravel
WYOMING															
North Bench Drainage District	1.88			3.74	3.74	9.0	Sept. 1922	1.83		.49	Sept. 1922	1.78		.48	Gravel,very compact.
Experiment Station.				.99	.99	5.0	Sept. 1908	1.20		1.21	Sept. 1908	1.00		1.01	Sandy gravel.
Shoshone Project	74.78	47.59	81.16	104.49	185.65	8.5					July 1923	232.0	4.87	1.25	Gravel,quicksand,shale and sandrock.
" " Area No.1	9.75	8.12	11.44	25.99	37.43						July 1923	43.8	5.40	1.17	Gravel.
" " " No.2	9.97	7.81	3.72	29.19	32.91						Aug. 1923	38.9	4.98	1.18	Gravel.
" " " No.3	4.12	3.44	2.56	9.44	12.00						Aug. 1923	17.6	5.12	1.47	Gravel.
" " " No.4	15.11	10.16	1.68	30.79	32.47						July 1923	47.6	4.69	1.47	Gravel.
" " " No.5	1.51	.94		1.88	1.88						July 1923	4.88	5.19	2.60	Gravel and sand.
" " " No.6	2.45	1.25	.38	3.16	3.54						July 1923	6.56	5.25	1.85	Sandy clay.
" " " No.7	25.47	13.06	55.85	1.61	57.46						July 1923	67.0	5.13	1.17	Quicksand,sandrock and shale.
" " " No.8	3.82	1.56	1.09	2.43	3.52						July 1923	6.60	4.23	1.88	Varies.
" " " No.9	2.58	1.25	4.44		4.44						July 1923	5.34	4.27	1.20	Clay.

In order to classify the information and make comparisons, it has been necessary to rearrange much of it and to reduce the results to standard units. The units most commonly employed are second-feet per square mile of area and second-feet per linear mile of drain, for maximum discharge; and acre-feet per acre and per cent of total water applied, for total annual yield. Except as applies to the unit second-feet per linear mile of drain, wide variations have been found in methods of arriving at unit values, because of different interpretations of the terms tributary area and water applied. Several of the various synonyms of tributary area are, affected area, irrigated area contiguous to drainage system and exclusive of remote but higher land, protected area, and total area of entire watershed regardless of the amount irrigated. All but the last one are difficult to outline, and when the term affected area is used as a basis it is found in some cases that the maximum rate of discharge and total run-off exceed the rate of application and total water applied, respectively. In the case of an intercepting drain, the protected area and tributary area are not identical. The use of area of the entire watershed often gives results that are not comparable, owing to great variation between districts with respect to the percentage of the area irrigated.

In the following tables usually two different areas are given under the heading "Tributary area". "Total area" means all land tributary to the drain from the standpoint of surface topography and which is below the highest canal or lateral. This area may or may not include the entire watershed and it may include rough or very sandy land which is not irrigable. Total areas are given to indicate the extent of unirrigated land, and because in some cases figures on the area of irrigated land were not available. "Irrigated area" means that part of the total area to which irrigation water is applied. The irrigated area has been used as the basis for

unit discharge or run-off. This basis like all others has serious faults; it assumes that the underground water surface conforms, at least in extent, to the ground surface, and that the entire irrigated area contributes or helps to contribute water to the drainage system. It disregards any underground inflow to the area from higher unirrigated lands, if such exists. It does not show the difference in unit yield that may exist as between an area where all of the irrigated land is in one body and another where it is more or less scattered over the total area. However, this basis will give results that are more nearly comparable than those derived from any other basis, when data from a great variety of drainage systems are considered.

Some data are included for districts on which the drainage system, at least in part, consists of a large number of deep wells from which water is pumped. It is far more difficult to estimate, even roughly, the area which is tributary to the drains of such projects than is the case for those which have only gravity drains.

Table 3 gives the total annual yield from a large number of districts, and the monthly yield expressed as a percentage of the total. The quantity of water delivered, the quantity diverted, the precipitation, and the annual yield are all expressed in acre-feet per acre of irrigated area. The total yield is shown as a percentage of the water diverted, plus the precipitation. This basis takes into consideration losses from canals and laterals on the total area, and precipitation on irrigated area only. Here again different investigators have used varying methods. Some have considered only irrigation water delivered to the land, some have disregarded precipitation, while others have included precipitation

on the entire tributary area. The first-mentioned method does not give consistent results, because in about one-third of the cases for which data are available the total annual yield exceeds the quantity of irrigation water delivered to the land.

The effect of precipitation on drainage flow varies with several factors and on many projects its influence must be rather slight when compared with that due to losses from irrigation. On a few projects precipitation during the growing season is of some importance, and on others the precipitation affects the flow during the later winter and early spring, especially where snow melts rapidly. Some projects have large unirrigated tributary areas above the highest canals, and while the precipitation may be low the aggregate amount in acre-feet per year is very large; but if this be included in water applied when expressing drainage yield as a percentage, the result is likely to be a very low figure compared with that for a district that has very little unirrigated land but that is otherwise similar. A rain is likely to have a greater effect on the flow of drains when it occurs simultaneously with irrigation than at other times, and generally the effect of precipitation on the water table will be greater on those areas where the water stands near the surface of the ground than on those where depth to water is considerable. For these reasons precipitation on unirrigated land has been disregarded in preparing the tables. In a very few cases presented it probably would have been well to consider precipitation on the total area, but in the interest of uniformity the same basis has been used throughout.

Direct waste from irrigation systems was not included in figures giving the quantity of irrigation water diverted to an area, except where its exclusion was impracticable. Where drainage water was used within the

project, the amount was included both in the water diverted and in the drainage yield.

Some open drains receive direct waste from canals and laterals. An effort has been made to exclude data for drains which receive large amounts of such waste. In other cases where the records were available the direct waste was deducted from the discharge figures.

Practically all open drains receive surface waste from farms, and this item is included in the figures presented. Many underdrains also receive farm waste; in fact, most of the data on underdrains include such waste, those for Utah being notable exceptions. Since the care of both seepage inflow and farm waste is required of all open drains and of many underdrainage systems, consideration of it seems to be necessary when presenting information for purposes of design.

Table 4 presents data on maximum rates of yield for a large number of drains. In many cases both the maximum recorded discharge and the maximum monthly rate of discharge are given. Detailed figures were not always available to show both, and lack of this in many cases has made it necessary to use a calendar month instead of the highest 30-day period. In analyzing the data more attention has been given to maximum monthly rates of discharge than to the highest recorded discharge. The former is apt to be the more accurate and its use leads to results which are more nearly comparable. However, data on both are given wherever possible, and Table 2 shows for average conditions the allowance that must be made in order to care for maximum daily discharge.

EFFECT OF VARIOUS FACTORS ON DRAINAGE YIELD

The factors that influence the yield of drainage systems are numerous and varied, and many are interrelated. In some cases when comparison of two different systems is attempted the variation in the effect of one factor may be so great that the effect of others is obscured. Field investigations are seldom if ever sufficiently comprehensive to make possible, with any degree of precision, determination of the effect of a single factor, since the combined influence of the others is never identical in any two areas that may be considered. This of necessity requires the use of general terms and expressions in a discussion of the subject.

On irrigated lands most of the water reaching the drains is the irrigation water. The nature of the soil and of the formation immediately below it is one of the factors determining the quantity of water which must be diverted to a project. It is also one of the principal factors influencing the rate of movement of ground water and the discharge of drains, and customarily the drainage yields are classified according to the general characteristics of the formation, particularly those of the subsoil.

Subsoil and Soil

The velocity at which water moves through a column of soil is said to be directly proportional to the difference in pressure at the ends of the column, and inversely proportional to the length of column. In a general way, the variation in velocity of flow through a homogeneous soil toward a drain is indicated by the slope of the water table. Other things being equal the velocity varies with the permeability of the formation. Clay has greater porosity than coarse sand, but the latter

has greater permeability and offers far less resistance to the movement of water. When water is applied to the surface of a sand formation the percolation losses are likely to be large, but such a formation has the capacity for transmitting water toward a drain at a rapid rate.

Aside from the fact that other influences affecting the quantity of water that reaches a drainage system are always present, it is difficult to classify discharge data according to the characteristics of the formations. Conditions are never uniform along a drain of any considerable length, and it is necessary that the classification be based upon predominating characteristics. Moreover, the discharge is influenced not only by the character of the formation along the drain but also by that of the entire area it serves, which may vary widely. Information available at present makes necessary the use of a small number of classifications; as a result there is room for a wide variation in degree of permeability within a single class. Gravel formations vary greatly; some are cemented, while others contain a mixture of well graded finer material which causes compactness, and if a large proportion of clay is present the degree of permeability may be quite low. Clay may contain many checks and cracks through which the water moves freely, and joint-clay formations permit the passage of water with a facility almost equal to that of sand. Because of jointing and crevices, some rock formations, such as lava and shale, carry water much more freely than others.

Data are presented in Table 5 which indicate the rate of movement of seepage water into open drains. These measurements were made on the Pioneer and Nampa-Meridian District, Idaho, in June, 1917, and

in the majority of cases they do not represent maximum flow. All the drains were open and the average wetted perimeter, or wet area through which the water was seeping, was determined for each section. The width of section varied from 8 to 14 feet. Some of the gravel and sand formations in this district are quite compact and show a very low discharge per linear mile of drain. The table shows considerable variation within each classification.

Table 5.- Seepage inflow into open drains on the Pioneer and Nampa-Meridian District, Idaho

Soil	Sections measured: Number	Sections measured: Total length	Seepage inflow: Per square foot of wetted area, in 24 hours: Low	Average	High	Per mile of drain
		Miles	Cu.ft.	Cu. ft.	Cu. ft.	Sec. ft.
Coarse sand, with clay at intervals	9	17.6	1.0	2.2	5.7	2.6
Coarse sand	15	42.5	0.9	2.9	5.6	2.5
Gravel and sand, fairly compact	8	23.7	0.8	1.9	2.8	1.5
Gravel and sand, quite compact	8	31.6	0.6	0.9	1.3	0.8
Gravel, open formation in area below reservoir	1	1.3		9.3		8.5

Wherever possible, drains are so located that they will reach into the more pervious formations, and while the velocity of flow depends upon the characteristics of this stratum, other formations either above or below it may tend to reduce the supply. Where the soil is heavy to some depth, or where clay or other dense formations exist at intermediate depths, the percolation from irrigation will be much less than where soil conditions are otherwise; consequently the drainage system will receive less water. The formations below grade depths have considerable influence because of the amount of natural drainage they provide. In some cases pervious formations exist below grade depths which become contracted or are taxed beyond their capacity toward the lower end of the district, and this causes a pressure condition necessitating the use of relief wells. Drains may be situated in a stratum of sand or gravel that is quite thin and underlaid as well as overlaid with rather impervious material, so that the cross section through which the greater part of the water moves toward the drain is reduced. Again, the permeable formation may have considerable thickness at the location of the drain and yet be of limited extent laterally.

Table 1 shows average results with respect to total annual yield and its relation to water applied, for the three main groups of subsoils. The data relative to this subject did not permit further divisions, since frequently information was not available on the separate portions of a project and it was necessary to classify them in a very general way according to the predominating formation. Some of the districts considered as belonging to group 1 contain considerable soil less permeable than is indicated, and many of those in group 3 had a large amount of

sandy subsoil. However, the averages show clearly that the total annual yield and per cent of water applied increase with the permeability. For groups 1, 2 and 3 the total annual yields were respectively 2.86, 2.39, and 1.28 acre-feet per acre, and the annual yields in per cent of total water applied were 42.6, 35.1 and 26.2 per cent, respectively.

In presenting average results on maximum rates of yield it was possible to divide the three main groups of subsoils into classes. The results given in Table 2 show that these yields increase with the permeability of the formation at grade depths and also with that at intermediate depths. The maximum monthly rate of discharge, in second-feet per square mile of tributary irrigated area, ranges from less than 1 where the formations are very dense, to more than 10 for open gravel formations. In this table the average for each class is given and also the limits for each as indicated by the columns "Low" and "High". In giving these limits, extreme and unusual cases were in most instances not considered; however, the upper limit given for class A, group 1, was the highest of any record available. For this class no data were available which would permit the making of even a rough estimate of the tributary area, and the figures are given only in terms of second-feet per linear mile of drain. The figures for this class are extremely high, and while they are based on data more meager than those for the other classes, yet they represent the results of measurements at nine outlets with 42.5 miles of drain, located in four different States.

It will be noted that the limits given for each class in Table 2 show a wide range, and that in most cases the upper limit of one class overlaps the lower limit of the next class. This in part is attributable to variations in formation, as explained above, but there are many

other factors which cause the maximum yield to deviate widely from the average, and of these the quantity of water used is important.

Water Applied

In the preceding paragraphs it was shown that drainage yield increases with the permeability of the formation. This is because water passes through gravel more readily than through clay formations and, owing to greater percolation losses from the former, the supply is greater. Where percolation losses are large the diversion duty of water will be low. As a very general statement it may be said that the greater the total quantity of water applied (water diverted plus precipitation) the greater will be the total annual drainage yield. There are numerous exceptions to this rule and these are more likely to appear in the consideration of areas containing dense formations, small districts, and districts having a high duty of water. For districts characterized by gravel formations it appears that the ratio of total annual yield to total water applied increases very rapidly after the latter begins to exceed 6 acre-feet per acre.

Table 1 shows that the average total application for those areas belonging to group 1 is slightly less than that shown for group 2, yet the drainage yield when expressed as acre-feet per acre, or as a percentage of the water applied, is greater in the case of the first group. All of these figures are lower for group 3 than for the others. In comparing these groups the effect of total water applied is obscured somewhat by the fact that a majority of the areas in group 2 are in the South where the irrigation season is long. However, this group included

some northern districts and its weighted average showed that 84 per cent of the total quantity of irrigation water was diverted during the period April to October, inclusive. It also happens that the irrigation systems of the projects considered in group 2 lose water much more heavily than the others. These difficulties in making comparisons were far greater when total yield and its relation to water applied were under consideration, than was the case when maximum rates of yield were compared.

When total annual yield is expressed as a percentage of the total water applied the results may vary widely between districts in the same class, but still remain more or less constant from year to year in a single district, particularly in one where other conditions do not change materially. Even with considerable changes in total tributary irrigated area, total quantity of water applied, and length of drainage system, the percentage may not change greatly. This tendency is illustrated in Figure 1, which shows, for two or more years, the relation between the total annual yield or run-off, and total application, for each of several districts.

Referring to the figure, the tributary irrigated area on the Umatilla Project and the Umatilla Drainage District, Oregon; the Minidoka Project, Idaho; and Sulphur Creek Wasteway, Yakima Project, Washington, did not change greatly during the period of record. On the other projects the tributary irrigated area increased during the period of record. On Yakima County Drainage District No. 2, Washington, the tributary irrigated area in 1916 was about 6,200 acres; during the period 1921-1924 it remained at about 10,320 acres, and for the period

1925-1926 it was 11,000 acres. During the entire period the length of the drainage system did not increase materially. On the Wapato Project, Yakima Indian Reservation, Washington, the tributary irrigated area increased during the period of record from 35,870 to 73,290 acres. The length of the drainage system from 1913 to 1918 remained at 42 miles but by 1925 it had been increased to 115 miles. Notwithstanding these changes the percentages given in Figure 1 do not show wide variation. The greatest variation occurred in the Umatilla Drainage District where for the second year of record there was a very large decrease in the quantity of water applied from that of the first year. Where considerable changes occur in duty of water from year to year it would be expected that the ratio of run-off to application would change somewhat, and in such cases average results for a series of years are needed to show the relationship.

While the percentages given in Figure 1 do not show wide variation it should be remembered that many factors influence run-off and some changes in conditions such as, for example, a considerable increase in the depth of the drainage system, probably would alter the relation of run-off to application.

Table 6 shows the relation of total yield to total water applied, to total irrigation water diverted, and to total irrigation water delivered. The figures show that the more permeable the formation, the higher the percentage of yield. This table, as does Table 3, shows wide variations from averages. Districts having very permeable formations and a low duty of water may show a percentage much higher than the average. For districts having clay or other dense formations, yield increases with the application but not necessarily in the same proportion.

While the figures for this group do not warrant a definite conclusion, they indicate a tendency for the ratio of drainage yield to water applied to decrease slightly with increase in application. If this be true it may be due in part to the fact that evaporation is greatest when the duty of water is low.

Table 6.- Relation of drainage yield to water applied

Group	Annual run-off in percentage of total water applied (Water diverted plus precipitation)			Annual run-off in percentage of irrigation water diverted	Run-off in percentage of irrigation water delivered.	
	Low	Average	High		For period April to October, inclusive	For year
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
All districts		30.9		35.3		56.3
All districts excluding those that pump from wells		36.5		41.4		70.2
1. Gravel or sand and gravel	25.8	42.6	81.8	49.3	37.1	69.4
2. Sand	18.8	35.1	69.0	38.1	32.2	85.7
3. Clay, silt, hard-pan or other dense formation	13.4	26.2	33.1	31.5	24.1	51.2

The last column in Table 6 shows that the drainage yield is a high percentage of the quantity of irrigation water delivered to the land. As already stated, in many districts the drainage yield exceeds the water delivered. This would suggest that losses from irrigation systems are an important source of supply for the drains. Cases have been noted where the discharge of drains increased greatly soon after water was first turned into the irrigation system and before any had been delivered to the

land. Table 7 shows average losses from irrigation systems for the different soil groups, and the average annual yield in acre-feet per acre. The average for all data considered shows that the annual drainage yield is almost identical with the irrigation system losses. In about half of the districts included in the table the former is less than the latter. In general, the greater the canal losses the greater will be the drainage yields although the average for group 2 appears to be an exception to this statement; but the canal losses for this group are very large. While the averages for a large number of districts tend to show that the drainage yield is about the same as the irrigation system losses, this does not necessarily indicate that the elimination of these losses would entirely remove the need for drainage systems.

Table 7.- Average losses from irrigation systems compared with average annual drainage run-off

Group	Annual loss from irrigation systems per acre	Annual drainage run-off Per acre
	Acre-feet	Acre-feet
All districts	1.94	1.84
All districts excluding those which pump from wells	2.33	2.35
1. Gravel, sand and gravel	1.68	2.86
2. Sand	3.49	2.39
3. Silt, clay and hardpan	1.57	1.28

Table 8 shows the relation of maximum monthly yield to maximum monthly rate of application. In this table precipitation is not considered. Fewer records were available on these maximum yields than on annual yields, but on the whole it is indicated that the rate of yield varies with the rate of application. Where the formations are very permeable, but few days are likely to elapse between occurrence of maximum diversion and that of maximum drainage discharge. In other formations the maximum yield may occur from one to two months later.

No data were available for districts having extremely and uniformly dense formations, but group 3 in Table 8 shows results for districts where the subsoil consists of clay and fine sand with the former predominating. The few figures available for this group showed but little variation with respect to water applied. Districts belonging to each of the other groups showed that drainage yield increased with the application. For gravel formations it appears that the ratio of maximum monthly yield to maximum monthly application increases quite rapidly after the latter begins to exceed 1 acre-foot per acre. This ratio is likely to exceed 40 per cent for districts that have very pervious formations and a very low duty of water. Districts having very compact gravel formations or gravel overlaid with a dense stratum, and which have a considerable tributary area remote from the drains, may show less than 20 per cent.

The total quantity of water applied and the rate of its application are very important factors to be considered in connection with annual and maximum yields of drains. With respect to maximum discharge, the wide variations in limits for each class are to a considerable extent

Table 8.- Relation of maximum monthly run-off to maximum monthly diversion duty

Group	Total irrigated area of districts considered	Maximum monthly diversion duty per acre			Maximum monthly run-off per acre			Run-off, in percentage of water diverted		
		Low	Average	High	Low	Average	High	Low	Average	High
	Acres	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Per cent	Per cent	Per cent
1. Gravel, sand and gravel	244,390	0.91	1.17	1.75	0.17	0.40	1.09	18.7	34.2	62.2
2. Sand	206,476	.72	1.07	1.68	.14	.28	.35	19.4	26.2	35.7
3. Clay with some fine sand	61,462	.71	.77	.78	.11	.16	.21	13.6	20.8	29.8

attributable to differences in duty of water and in canal losses. The characteristics of the crops, climate, and soil do not always determine the duty of water. In some districts water is cheap and plentiful, and where that is the case more water is likely to be used than is necessary, with consequent large drainage yields.

While irrigation water is the primary source of supply of drainage run-off, the relationship between the two is not very direct because the water which reaches the drains is that portion not taken by crops, evaporation, and natural drainage. These factors, especially the last one, may vary widely.

Natural Drainage

The influence of natural drainage on the discharge of artificial systems is important and its extent is difficult to estimate. Natural drainage exists in some degree on the majority of projects. Often the natural underground inflow is also an important item to be considered.

Some districts have large, dry, tributary areas above the highest land irrigated. Where the soil is fine-grained, the depth to water table great, and the precipitation low, it seems probable that the underground flow from such areas is a relatively unimportant factor. Precipitation on such areas and on unirrigated areas within the district has been disregarded in the tables in this bulletin. However, in the cases of the Carmel Drainage District, Colo., and the Umatilla Project, Oreg., the difference between total water applied and the total drainage yield hardly seems sufficient to produce crops. This is especially true for the latter project, where it probably would have been preferable to consider precipitation on the entire watershed.

Artesian water is present under some districts and is used, at least in part, as an irrigation supply. Where this is the case it is possible that, to some degree, water may escape through the stratum overlying the artesian supply, especially since very frequently well casings leak badly. Artesian water is found in the Carmel Drainage District and in districts in the vicinity of Roswell, New Mexico.

Some projects are so situated as to receive seepage losses from river channels at least during portions of the year, and in such cases the underground inflow is likely to be an important factor. Examples of such projects are Palo Verde District, Calif., Yuma Project, California and Arizona, Rio Grande Project, New Mexico and Texas; Lincoln County Drainage District No. 1, Nebr.; and Wapato Project, Wash. Most of these stand high in their respective classes with regard to maximum yield.

Table 9 shows differences between water applied and drainage yield, for various groups. The average for all projects considered indicates the difference between total annual application and total annual yield to be a little over 4 acre-feet per acre. This amount seems to be somewhat larger than should be required for evaporation and use by crops, and part of it probably represents natural drainage. In any event Table 1 gives examples where the difference exceeds 5 acre-feet per acre by a considerable amount and obviously the natural drainage must be considerable in such cases.

Table 9.- Differences between water applied and drainage run-off

Group	Annual drainage run-off, per acre	Difference between total water applied, (water diverted plus precipitation), and drainage run-off for the year, per acre: Low	Aver-age	High	Difference between water diverted and drainage run-off for the year, per acre	Difference between water diverted and drainage run-off for the period April to October, inclusive, per acre	Difference between water delivered and drainage run-off for the year, per acre
	Acre-ft.	Acre-ft.	Acre-ft.	Acre-ft.	Acre-feet	Acre-feet	Acre-feet
All districts	1.84		4.11		3.37		1.43
All districts excluding those which pump from wells	2.35		4.08		3.33		1.00
1. Gravel, sand and gravel	2.86	1.83	3.85	5.17	2.94	3.65	1.26
2. Sand	2.39	2.54	4.42	5.64	3.89	3.59	.40
3. Silt, clay and hardpan	1.28	2.27	3.60	4.01	2.79	3.09	1.22

It has frequently been assumed that an area having a fair slope and underlaid with gravel or other permeable material will not require drainage. However, when such areas do require drainage - and many of them do - the developed run-off is generally much greater than from those projects which apparently had much lower natural drainage capacity. The very factor which seems to be an insurance against the need for drainage may make necessary the diversion and application of such liberal quantities of water for irrigation that the natural drainage capacity, even though large, becomes overtaxed to a greater extent than is the case on a project having a less permeable formation and possibly a high duty of water.

Table 9 shows that the difference between total water applied and total drainage yield is greater for group 2 than for the other. Possibly one of the reasons lies in greater transpiration and evaporation losses in group 2, as the majority of the districts of that group are in the South. Taking this into consideration it would appear that on the average the natural drainage for the three main groups does not vary greatly. However, wide variations occur within each group.

Under certain conditions the effect of natural drainage may be a rate of maximum discharge which is high when compared with the average annual discharge. Some drains go dry during the non-irrigation season and the water table recedes below them. Some of the drains listed in Table 3 have very low flow or no flow at all during the winter months. On portions of the Wapato Project, Wash., drains that have very high discharge during the height of the irrigation season are dry during the winter, and in some cases the water table recedes to a considerable depth below the bottoms of the drains, which are relatively deep.

Some districts are characterized by approximately horizontal strata which are more or less impervious and which outcrop at intervals along the slopes; others have relatively permeable formations on the whole, but are traversed by dykes of hardpan or rock which retard or prevent natural drainage. The Umatilla Project, Ore., shows a very small difference between total water applied and total drainage yields - a fact that seems to indicate that the amount of natural drainage is quite small. The main drainage system on this project is in very permeable formation, particularly at the lower end, but the extreme lower end of the main drain cuts deeply through a rock ridge or dyke. Both the annual and the maximum rates of yield are very high from this system.

When all irrigation projects are considered it is obvious that, all other things being equal, the quantity of water requiring removal by artificial means varies inversely with the amount of natural drainage, and some irrigation projects and portions of all do not require artificial drainage. However, considering only those irrigation projects for which drainage systems have been required, it is generally found that those which apparently have large natural drainage capacity have needed large quantities of irrigation water, and that their drainage yield has been correspondingly high.

To some extent, the wide variations from the average figures for maximum discharge given in Table 2 are caused by lack of natural drainage. The effect of this factor on required capacity of drainage systems must be considered in connection with others such as use of water, character of formation, and topography.

Topography

Variations on topography may affect, or even entirely control, the locations of drains, and systems so affected will generally have run-off characteristics differing from those on flat lands. Assuming that the difference between total water applied and total drainage yield is an index, those projects having the greatest differences in elevation within their boundaries show the greatest degree of natural drainage, as would be expected. However, this does not necessarily mean that the yield from artificial drainage systems will be low. Steep slopes over a suitable formation may permit steep slopes of the water table without damage to the land, and the natural drainage will be good particularly if the area slopes in one general direction and the required drainage system has several outlets widely spaced. On the other hand, steep slopes on the upper part of the project may serve merely to concentrate the excess water on the lower and flatter portion. This is also the case where the affected area is in a narrow valley or draw, or where a drainage system is required in a valley which converges to a rather narrow outlet.

Mention has already been made of projects so situated that the natural underground flow into them is large; and a long, narrow area such as the Rio Grande Project which receives inflow from a river will receive more in proportion to its area than will one more compact. Such a project may have a great length of main irrigation canals for a unit of area, and great seepage losses; and the drains must necessarily be located close to some of them.

Characteristics of topography may affect the duty of water and the quantity of surface waste from farms.

Surface Waste from Farms

Most of the discharge data presented include farm waste. Some figures on the amount of this waste are presented in Tables 10 and 11. The amount of waste varies widely and is apt to be quite large during the early part of the irrigation season. On Yakima County Drainage District No. 2, Washington it has been observed that surface waste is less during the height of the irrigation season than at other times.

Table 10.- Farm waste in drainage discharge

Location and name of project	Date of record	Length of drain	Total discharge of drain	Farm waste: Total	Farm waste: In proportion of total discharge	Farm waste: Per mile of drain
		Miles	Sec. ft.	Sec. ft.	Per cent	Sec. ft.
IDAHO						
Canyon County, Drainage District No.1	Oct.1923	17.0	80.0	30.0	37.5	1.76
Nyssa Arcadia Drainage District	June 1918	14.3	24.6	7.9	32.1	.55
Nyssa Arcadia Drainage District	Aug.1923	14.3	25.8	7.0	27.1	.49
Payette County, Drainage District No.1	Aug.1923	4.9	10.0	2.0	20.0	.41
Payette County, Drainage District No.1	Aug.1923	4.9	9.7	2.0	20.6	.41
Pioneer Nampa-Meridian District 1/	June 1917	127.5	318.9	83.6	26.2	.66
Pioneer Nampa-Meridian District 1/	Aug.1917	127.5	341.5	97.2	28.5	.76
Pioneer Nampa-Meridian District 1/	Oct.1917	127.5	275.5	49.5	18.0	.39

1/ Direct waste and inflow at head of construction not included.

Table 11.- Relation of farm waste to monthly run-off and to total for the period April to October, inclusive

Location and name of project	Length of drain	Year of record	Farm waste: In percentage of monthly run-off: Apr.	May	June	July	Aug.	Sept.	Oct.	In percentage of total run-off for period Apr. to Oct. inclusive	Per acre	In percentage of water delivered
	Miles		P.ct	P.ct	P.ct	P.ct	P.ct	P.ct	P.ct	Per cent	Ac-ft.	Per cent
IDAHO												
Boise Project, Lower Division												
Boise Project, Lower Fargo Basin	5.8	1920								18.8	0.25	6.1
Boise Project, Lower Lake Drain	4.2	1920	6.8	15.1	30.5	17.2	4.9	0.6	0.0	12.5		
Pioneer Nampa-Meridian Drainage District	127.5	1917	44.7	42.5	37.7	32.4	36.1	36.1	23.8	35.9		
Pioneer Nampa-Meridian Drainage District	131.4	1920	34.9	46.1	42.1	31.7	29.5	21.2	5.7	32.1	.41	9.8
WASHINGTON												
Yakima County Drainage District No. 2	29.3	1916								15.3	.17	6.0

As a general rule it appears that open drains receive more farm waste per unit of area than underdrains. With respect to maximum rates of discharge, and particularly to the maximum daily rate, surface waste is likely to comprise a greater percentage of the total in drains in tight formations and carrying small seepage flows, than in those in pervious formations and carrying large seepage flows.

Table 2 gives maximum daily discharges in percentages of the maximum monthly rates. It will be noted that the averages for sand and gravel show a higher percentage where the formation at intermediate depths is clay or other dense material, than where such is not the case. This may be attributable to differences in the amount of surface waste. The averages are not given for group 3, but the variations are shown to be quite large particularly for class B of this group which includes tight formations. For group 3, the daily maximum discharge in percentage of the maximum monthly rate is quite low for underdrains and frequently very high for open drains. When the maximum daily discharge is high as compared with the maximum monthly rate, it is usually the result of a large increase in farm waste. Weighted averages of 11 outlets with 116 miles of drain, all in gravel, showed the maximum daily discharge and the maximum 7-day rate to be 116.4 and 110.4 per cent, respectively, of the maximum monthly rate of discharge.

Low delivery duty of water and steep slopes tend to cause large amounts of surface waste which vary also with the kind of crops grown and the methods of applying water.

Crops and Methods of Applying Water

If it were possible to determine the amount and rate of deep percolation losses it would not be necessary to take into consideration either the quantity of water applied or the kinds of crops grown. Deep percolation losses may be divided into two classes - those occurring on the main irrigation system, and those taking place after the water has been delivered to the farms. Frequently, data are available on the former, but the latter must be estimated. It has been pointed out that average figures for a large number of districts seem to show that losses from main irrigation systems constitute the more important contribution to drainage yield. However, wide variations from the average occur, and in one case the total annual yield exceeds the irrigation system losses by about 5 acre-feet per acre. In such cases deep percolation losses on the land are the more important factor.

Different crops require different quantities of water and this fact needs to be considered in connection with delivery duty of water. Other things being equal, low duty results in large percolation losses. Rice requires much more water than other crops but no projects are listed herein on which rice is grown to any great extent. Of the more common crops alfalfa appears to stand highest in the use of water; it requires much water throughout the season unless grown for seed. Alfalfa seed is produced to a considerable extent on the drainage districts in Millard County, Utah. Grain requires less water than alfalfa hay and the period of use is shorter. Sugar beets are an important crop on several projects. They require late irrigation. On five of the large projects listed, cotton is the principal crop, with alfalfa usually next in importance. On most of the others alfalfa is the principal crop and with but few exceptions grain is the next in importance.

The care used in levelling the land, methods of tilling, and systems of crop rotation used have some effect on the use of water. The furrow or corrugation method of irrigation is apt to result in both greater percolation losses and greater surface waste than most other methods. Greater care in applying water is usually exercised where the rotation system of delivery is practiced, and where large portions of a project alternate in the application, the required capacity per unit of area needs to be greater for branch and lateral drains than that for the main outlets.

The use of water is influenced not only by the kind of crops grown but also by many other factors, an important one being climate. Other things being equal, the actual use of water will vary with the temperature.

Climatic Conditions

The yield of drains is influenced to some degree by climatic conditions mainly because of resulting differences in use of water and length of irrigation season. Variations in temperature and barometric pressure affect the rate of flow of groundwater into drains, but the effect of these is rather small and is not taken into consideration in the design of a drainage system. Continuous records on Yakima County Drainage Districts Nos. 2 and 25, Washington showed very marked diurnal fluctuations in flow, the greatest discharges occurring in the early morning. Since these variations occurred only during the irrigation season they probably were the result of fluctuations in farm waste. However, data on these districts showed that a considerable rise occurred in the water table during the fall and early winter of one year, while at the same

time the flow was decreasing. This might have been due to the effect of temperature on the rate of movement.

In nearly one-third of the cases given in Table 3 the monthly yield shows a small decrease in midsummer. This may be attributable in part to fluctuation in farm waste, but more likely it is caused by a higher rate of transpiration and evaporation at that season.

Precipitation varies from very low on districts depending entirely on irrigation water, to relatively high on those which merely use irrigation water to supplement the natural supply. On the majority of the projects listed, precipitation is not regarded as an important factor in crop production. On some, the most apparent effect of precipitation is that caused by rapid melting of snow, which usually occurs in February or March. Instances have been noted where apparently, rains during the summer temporarily increased the drainage flow somewhat out of proportion to the precipitation. Probably this was due in part to marked decreases in transpiration and evaporation during several days of cool, cloudy weather. However, a heavy rain occurring shortly after the application of irrigation water or when the water table is high, will have a marked effect on the drainage discharge, and consideration should be given to this probability when designing a system for an area subject to heavy summer rains. Precipitation on Lincoln County Drainage District No. 1, Nebraska, is occasionally greater in one month than the annual precipitation on some of the projects. Although none such is listed herein there are irrigation projects that occasionally receive such heavy precipitation that it becomes the principal factor to be considered in designing the drainage systems.

The effect of length of irrigation season on drainage yield is not clearly demonstrated by the data available, but it is likely that a project having a short season and a low duty of water will have a monthly maximum yield which is a very high percentage of the total annual yield. For the listed projects having short seasons the duty appears to be comparatively high, and regardless of the relation of the maximum rate to the annual rate of yield, the maximum rates of discharge per square mile were not high; in fact, they were rather below average. In Table 2 the average maximum monthly yield in percentage of the total yield is less for group 2 than for groups 1 or 3. This no doubt is because many of the districts considered in group 2 have a very long irrigation season.

Type of Drain

Average figures show that open drains have a greater discharge per unit of length than underdrains, but this is due to the wider spacing and greater depth of the former, and to the fact that underdrains generally receive less farm waste. Exceptions to the average figures occur, as in the case of the Yakima City West Side Drain, Washington, an underdrain which receives no surface waste at all but which shows the next to the highest discharge per linear mile. However, this drain is very deep, is in very open formation, and holes were provided in the bottom of the pipe for the entrance of the water.

Since most underdrains receive seepage inflow only through the joints of the pipe, the cross-sectional area through which the water passes at entry must be very much less than is the case with open drains.

In tight formations, at least, this is likely to reduce the inflow and to require relatively close spacing of underdrains, unless the joints of the latter are surrounded with pervious material. Where underdrains are properly constructed the spacing requirements and the yield per unit of length are probably not very different from those of open drains if the depths are the same. In tight formations the water table will have a very steep slope immediately adjacent to either type of drain, at least during the height of the irrigation season. If underdrains are improperly constructed, the material around the joints may become puddled and thus offer such resistance to flow that little or no lowering of the water table occurs and the drainage yield per unit of length is very low. However, the banks and bottoms of open drains in fine materials occasionally become puddled to some extent.

The data on underdrains occasionally show a comparatively low rate of maximum yield because their capacity is overtaxed. This is particularly true of underdrains in gravel.

An intercepting drain that reaches through a permeable formation to one that is rather impermeable to a considerable depth, is likely to develop somewhat greater flow per unit of area and length than is a relief drain similarly situated.

Depth of Drains

Drains are usually installed on irrigated lands for the purposes of reducing the fluctuations of the water table and preventing, so far as possible, its rise above a definite level in the soil and subsoil. If these objects are accomplished on a project where the natural underground inflow and outflow are negligible factors, an increase in depth of the

system would not increase the annual yield. In fact, because of greater reservoir capacity in such soil, the maximum rate of yield in a fine-grained soil might even be reduced very slightly. This effect would be more probable for small areas on which the rate of application of irrigation water is not uniform.

On several of the listed districts which have permeable formations, subirrigation is practiced to the extent that an effort is made to have the open subsoil well filled by the time the irrigation season is at its height. If this be done, it is obvious that the deeper drains will yield at a higher maximum rate.

Many projects have a considerable amount of underground inflow or outflow, or both, and an increase in depth is very likely to result in both greater annual and greater maximum yields because the deeper system will receive or intercept a larger amount of the natural flow. This is clearly evident in cases where, during the non-irrigation season, the water table recedes to some distance below the bottom of the drains. Moreover, if the system is quite shallow evaporation may take a greater proportion of the water than in case the water table is held well below the ground surface.

The system of Yakima County Drainage District No. 7, Washington, originally had an average depth of 6 or 7 feet. The subsoil was generally quite sandy, although the lower end of the system was in a hard clay formation. This system was later given an average depth of over 11 feet, with the result that the total annual yield was increased by about 120 per cent and the maximum rate of yield by over 160 per cent. Part of these very large increases was without doubt a reflection of the decrease in both evaporation losses and amount of natural drainage yield.

A discussion of the effect of depth on yield assumes that the formation remains unchanged. It is evident that in the case of a drain at the bottom of a permeable formation underlaid with a very dense material, the discharge, would not be materially increased if the drain were given a greater depth; in fact, the discharge might even be decreased if improper backfilling were used. In gravel and sand formations a considerable increase in depth is likely to result in an appreciably increased yield. The effect of depth on yield is closely related to that of spacing.

Spacing

Table 2 gives the average miles of drain per square mile of irrigated area for each subsoil group, but individual districts show wide variations from the averages. These figures do not represent the actual spacing of drains, since in many districts the affected area develops only on a part of the total area. The table reports 1.1 miles of drain per square mile of irrigated area for class B of group 1, which is a fair indication of the actual spacing for permeable formations. For tighter formations, as notably those in Group 3, the average distance between drains is generally much less than that indicated by the figures given in the table. For class B, group 3, the average distance between drains is about 1/8 mile, and in some cases it is much less.

Spacing affects the discharge per unit of length, but it does not influence the annual yield per unit of area except insofar as natural drainage is affected. These are likely to be small.

On many projects the locations of the drains depend upon topography and there is little or no relation between spacing and depth. On flat lands where drains are spaced uniformly, the effect of distance on maximum rate of discharge depends on the adequacy of the system and upon the rate of application of irrigation water. On large areas where the rate of increase of application is gradual and uniform, and where the drainage systems are adequate, two systems that are similar except for spacing will not show much difference in maximum yield per unit of area. However, in the case of small areas, such as single farms or any other areas where rotation is practiced, the sudden application of large quantities of water usually results in a greater maximum yield from the system having the closer spacing. This difference in yield is more noticeable in the maximum daily or the maximum 7-day rate than in the maximum monthly rate of discharge. If the application is such that the water table is brought to the ground surface, the maximum rate of yield from a closely spaced system will be much greater than that from one with wide spacing.

Size of Area

It has already been pointed out that the rate of application of water on small areas is likely to be far less uniform than that on a large district. Continuous records of discharge on the various portions of a drainage system almost invariably show that the maximum discharges do not all occur on the same date, and the opportunity for variation in time increases with the size of the area. Even though the unit rates of maximum discharge are identical on the various branches

of a system, differences in time of occurrence result in a reduced unit rate of maximum discharge at the outlet. Variation in the rate of natural drainage is apt to be greater in a small district than in a large one, and the drains may be nearer to the main part of the irrigation system. Such variations tend to make the maximum discharge per unit of area somewhat less on a large area than on a small one. Except in this indirect manner, size of area has no effect on yield per unit of area.

In connection with this subject consideration should be given to variations in unit rates of discharge that may occur within a district. Conditions may be such that these rates vary widely. As a general rule the unit rate of maximum discharge at the outlet of a main system is less than that of some of its laterals and more than that of others. On the Umatilla Project, Oregon, the lower mile of the system appears to develop nearly half of the maximum monthly yield. In this case the maximum unit rate of discharge at the outlet must be greater than that of any of the component parts of the system. Excepting one of its main branches, the outlet of Sulphur Creek Wasteway, Washington, shows a smaller maximum discharge per unit of area, for total irrigated area above the outlet, than any other drain.

In Yakima County Drainage District No. 2, Washington, the formation along the main drain, which is nearly 7 miles in length, appears to be fairly uniform and consists of a hard clay with thin strata and lenses of fine sand. The lateral system contains about 21 miles of drains serving narrow valleys or draws all of which are on one side of the main valley. Measurements made at numerous points showed in most cases that the unit rates of discharge per square mile of area and per linear mile of drain, for the areas and parts of the system above the

respective points of measurement, decreased as the measurements proceeded up stream. The inflow to the lower mile of drain was very much greater than that to the upper mile, and the decrease was fairly uniform as the measurements proceeded up stream. This was true not only of measurements made on the same day, but also of the maximum discharges for each section.

These examples serve to show that under some conditions of topography and underground formation the lower part of a drainage system may receive a much greater inflow per mile of drain than the upper parts. There are also examples where the opposite is true because of better natural drainage in the lower part of the district, or because the upper parts of the drainage system are situated to receive a large portion of the losses from the main irrigation system.

Location and Extent of Affected Area

When comparing a great variety of districts with respect to drainage yield, the total tributary irrigated area seems to be the best basis. However, the location and extent of affected area with respect to the total area should be taken into consideration. The upper parts of many districts are not affected and percolation losses on these higher areas may not influence the flow of the drains so quickly as do those on the lower areas directly served by the drainage system. Moreover, in such cases the deep underground formation may be such that a considerable part of the natural drainage does not move toward the main drainage system.

The Pioneer and Nampa-Meridian District, Idaho, contains a large area of irrigated land which is higher than and tributary to the lower part from the standpoint of surface topography, but which is rather remote from the drainage system. Unit discharges from this district are below the average for its class, and for one division are extremely low.

This division is a long valley which is nearly parallel with the Boise River, its upper end being much higher than the river. It seems likely that some of the irrigation water escapes directly to the river and this probably is true, but to a lesser degree, on the lower part which is served directly by the drainage system.

Extent of Irrigated Area

For all of the districts listed herein, the area irrigated averages about 74 per cent of the total area. The average for those considered in group 3 was less. A district that contains unirrigated land scattered throughout the total area is likely to show a lower rate of maximum discharge per unit of irrigated area than one in which a high percentage of its area is irrigated, if other influences remain equal. However, a district is apt to have a lower duty of water when only partially irrigated than after becoming more completely irrigated. Differences in extent of total area irrigated appear to have a greater effect on the maximum rate of yield than on the annual yield per unit of irrigated area.

In one district for which a long series of records was available, the irrigated area was increased about 77 per cent during the period of record, most of this increase being along the upper boundary. The subsoil of this district is not very permeable. During the period of record no additions were made to the drainage system. The effect of this increase in irrigated area was obscured to some extent by changes in other factors, but it appeared that the drainage yield in percentage of total water applied, and the maximum monthly yield per unit of irrigated area, remained about the same. The yield per linear mile of drain increased materially.

In another district which has a very permeable formation the irrigated area doubled during the period of record and the length of the drainage system, which was widely spaced, more than doubled. The annual yield in percentage of total water applied did not change materially. On the average, the maximum rate of discharge per linear mile of drain remained about the same, but the maximum rate of discharge per square mile of irrigated area increased by a large amount.

Miscellaneous Measurements

Data on a considerable number of systems which were not included in Tables 3 and 4, are given in Table 12. The figures are the results of single or isolated measurements.

GENERAL DESCRIPTION OF DRAINAGE SYSTEMS

Arizona

The Salt River Project is in south-central Arizona. With the exception of several abrupt rocky protrusions the land surface is regular. North of Salt River the Slopes vary from a few feet to 20 feet per mile. South of the river the area is flat.

The soils are chiefly sandy clay loam and loess; these absorb water at a moderately slow rate and hold it well. The top soil is underlaid by strata of clay and caliche which vary from thin layers to thicknesses of 100 feet or more. In places these strata are underlaid by extensive deposits of gravel and bowlders.

In 1918 the depth to ground water was 10 feet or less on 65,000 acres. A system of drainage wells was installed, and during the summer of 1925 water was being pumped from about 110 wells which had an average depth of 225 feet and diameters varying from 12 to 24 inches.

Table 12.- Miscellaneous records of drainage discharge of systems serving irrigated lands. These figures are the results of single or isolated measurements (Continued)

Location and name	Tributary area: Total area	Tributary area: Irrigated area	Length of drains: Open	Length of drains: Closed	Length of drains: Total	Average depth of drains	Date of record		Discharge: Total	Discharge: Per square mile of area	Discharge: Per mile of drain	Predominating subsoil
	Square Mile	Square Mile	Miles	Miles	Miles	Feet			Second Feet	Second Feet	Second Feet	
IDAHO												
Canyon County Drainage District No. 2	2.92		3.50	1.44	4.94		August	1921	4.50		.91	
Boise Project, Lower Division, Meadows Drain			.33		.33		July	1919	1.90		5.76	
Riverside Drain			.93		.93		December	1919	3.00		3.23	
Hurt Drain			.80		.80		September	1920	1.00		1.25	
OREGON												
Boise Project, Lower Division, Holly Drain			4.25		4.25		September	1920	2.22		.52	
Kilburn Drain			.40		.40		November	1920	2.00		5.00	
Okander Drain			.97		.97		September	1919	.80		.82	
Umatilla Project, Hat Rock Drain			1.4		1.4		September	1914	2.00		1.43	
Cold Springs Drain			1.5		1.5		September	1914	6.00		4.00	
Warm Springs District					56.0				132.0		2.36	
MONTANA												
Arnold Drain, Near Billings	8.25			3.30	3.30	8.0	September	1925	6.35		1.92	
Carroll Drain, Near Billings	1.03			2.23	2.23	11.5	September	1925	2.49		1.12	Gravel
Billings Drain, Near Billings	1.93			2.70	2.70	11.0	September	1925	5.00		1.85	Gravel
NEBRASKA												
Lincoln County, Drainage District No. 1				.50	.50	8.0	September	1925	3.00		6.00	Coarse sand and gravel
North Platte Project, Leavitt Drain	18.0				9.5		September	1925	90.3		9.51	
Fort Laramie Div., Gering Drain	23.0				16.8		September	1925	70.9		4.22	
NEVADA												
Truckee Meadows, Peoples Drain			5.3		5.3		September	1925	35.5		6.70	
North Truckee Drain, W. Branch			3.2		3.2		September	1925	22.9		7.16	
WASHINGTON												
McPhee Thompson Drain. Near Naches	.35	.31		1.04	1.04		September	1912	6.7	21.61	6.44	Gravel
WYOMING												
Bench Canal Drainage District, A Drain					11.8		September	1925	6.77		.57	
B Drain					3.9		September	1925	2.01		.52	
C Drain					1.5		September	1925	.84		.56	
Colter Drainage District, Drain No. 3					1.75		September	1925	.82		.47	
Drains 7 and 8					1.60		September	1925	1.48		.93	
Lovell Drainage District, Drain No. 1					1.81		September	1925	1.73		.96	Sand
No. 2					1.86		September	1925	.89		.43	Sand
Lovell Bench Drainage District, East Outlet					2.4		September	1925	.54		.23	
West Outlet					3.75		September	1925	1.60		.43	
Sunlight Drainage District, Drain No. 1					1.5		September	1925	1.75		1.17	
Drain No. 2					5.4		September	1925	5.44		1.01	
Drain No. 3					1.27		September	1925	.60		.47	
Worland Drainage District, D Drain					5.00		September	1925	.69		.14	

Table 12.- Miscellaneous records of drainage discharge of systems serving irrigated lands. These figures are the results of single or isolated measurements (Continued)

Location and name	Tributary area: Total area	Tributary area: Irrigated area	Length of drains: Open	Length of drains: Closed	Length of drains: Total	Average depth of drains	Date of record	Discharge: Total	Discharge: Per square mile of area	Discharge: Per mile of drain	Predominating subsoil
	Square Mile	Square Mile	Miles	Miles	Miles	Feet		Second Feet	Second Feet	Second Feet	
ARIZONA											
Salt River Valley, Maricopa D.D. No. 5			7.5		7.5	10.0	February 1923	34.7		4.63	Gravel and sand
Salt River Valley, Maricopa D.D. No. 5			3.0		3.0		February 1923	28.9		9.63	Gravel and sand
Salt River Valley, Maricopa D. D. No.5			6.7		6.7		May 1926	22.3		3.33	Gravel and sand
CALIFORNIA											
Imperial Valley			170.37		170.37		January 1927	63.41		.37	Silt with some fine sand
Ash Drain			1.5		1.5		January 1927	1.25		.83	
Central Drains			38.5		38.5		January 1927	9.05		.24	
Dixie No. 4			.36		.36		January 1927	1.00		2.78	
Dixie Drains			11.59		11.59		January 1927	2.30		.20	
Mt. Signal Drains			8.09		8.09		January 1927	1.00		.12	
Rose Outlet Drains			22.47		22.47		January 1927	3.15		.14	
Holtville No. 3			2.50		2.50		January 1927	4.85		1.94	
Holtville No. 1			4.50		4.50		January 1927	5.71		1.27	
Holtville No. 6			8.16		8.16		January 1927	11.81		1.45	
Holtville No. 7			2.14		2.14		January 1927	3.51		1.64	
Holtville System			61.51		61.51		January 1927	42.46		.69	
Moss Drain			.90		.90		January 1927	.72		.80	
Newhope Drainage District	5.58	3.50		21.20	21.20	8.0	February 1925	4.00	1.14	.19	Sandy loam
COLORADO											
Uncompaghre Valley, H. W., Baird Farm				.38	.38		August 1925	1.25		3.29	Gravel
Cook Farm				.49	.49		August 1925	1.50		3.06	Gravel
Keshaw Farm				.49	.49		August 1925	2.25		4.59	Gravel
A. Schafer W. Drain				.62	.62		August 1925	.75		1.21	Gravel
A. Schafer E. Drain				1.51	1.51		August 1925	1.00		.66	Gravel
Homer Graham Farm				.28	.28		August 1925	.75		2.68	Gravel
Brown Farm				.49	.49		August 1925	1.00		2.04	Gravel
Shale				.38	.38		August 1925	.60		1.58	Shale
Settle N. Drain				.28	.28		August 1925	.10		.36	Shale
Settle S. Drain				.38	.38		August 1925	.10		.26	Shale
Grand Valley, Jx System	1.11	1.06	3.04		3.04		October 1920	1.97	1.86	.65	)
M3x System	.50	.42	1.21		1.21		October 1920	.56	1.33	.46	)
B System	.95	.94	2.09		2.09		November 1920	1.73	1.84	.83	)
C1 and C0 System	3.99	3.91	4.85	.80	5.65		October 1920	2.59	.66	.46	)
D and Dx Drains	2.17	2.11	2.09		2.09		October 1920	1.00	.47	.48	)
D_{11} and E_{111}		.59	1.87	.17	2.04		October 1920	.87	1.47	.43	) Soils and
F System		1.94	3.87		3.87		October 1920	3.90	2.01	1.01	) subsoils are
G_1 System	.41	.36	1.55		1.53		October 1920	1.05	2.92	.69	) generally
G System	6.45	6.25	7.43		7.43		February 1920	2.03	.32	.27	) heavy and
H System	4.92	4.84	5.25		5.25		October 1920	3.36	.69	.64	) contain much
I_1 System		1.00	2.77		2.77		October 1920	2.67	2.67	.96	) clay
I System	5.86	5.78	10.25		10.25		January 1921	3.53	.61	.34	)
J Brain		1.13	1.84		1.84		September 1920	.72	.64	.39	)
J System	6.34	6.14	9.62		9.62		January 1921	2.38	.55	.35	)
M_{11} Drain		.45	1.24		1.24		October 1920	.79	1.76	.64	)
21 System		.78	1.64		1.64		October 1920	1.52	1.95	.93	)
Lewis Waste		2.97	4.84		4.84		January 1921	.52	.18	.11	)
Indian School Drains A_1 and A_2		.27	1.48		1.48		October 1920	.33	1.22	.22	)
Indian School Waste	7.97	7.66	10.83		10.83		February 1920	1.12	.15	.10	)
Leach Creek	12.50	11.72	21.00		21.00		January 1921	3.69	.31	.18	)
Little Salt Wash.	5.63	5.47	6.00		6.00		January 1921	1.52	.28	..25	)
Big Salt Wash	11.88	11.25	11.00		11.00		January 1921	7.05	.63	.64	)
Reed Drain	21.90	21.25	20.00		20.00		January 1921	9.23	.43	.46	)

The water is lifted about 33 feet. Spacing of the wells varies from one-half mile to one mile.

Part of the water pumped is used for irrigation. Irrigation water is sometimes applied throughout the year, but the diversions are relatively small during the winter months. The principal crops are cotton, alfalfa, grain, and fruit.

California

The Valley Division of the Yuma Project is in Southwestern Arizona. The Reservation Division is just across the Colorado River in California. The greater part of the project is flat river-bottom land with an average slope of 2 1/2 feet per mile. Levees are required to protect the low land from overflow during high water in the river.

The principal soil is sandy loam, although in a few places heavy adobe soil is found. The subsoil is generally fine sand.

Drains are generally of the relief type, and their locations are partly governed by topography. The drainage water is pumped into the river. The area estimated as protected in 1924 was 31,500 acres in the Valley Division, and 8,000 acres in the Reservation Division.

Irrigation water is used throughout the year but the use is relatively small during the winter months. The principal crops are cotton and alfalfa.

The Palo Verde District is on the California side of the Colorado River and includes the towns of Blythe and Ripley. The land is flat though traversed by sloughs and with a general slope of about 2 feet to the mile. It is protected from overflow by levees, and borrow pits serve as a part of the drainage system. The top soil con-

tains much silt, is rather impervious, and is underlaid by sand.

Irrigation water is applied throughout the year. The principal crop is cotton. The year of record in Table 3 begins with June.

The Kearney Vineyard Experimental Drainage Tract consists of 160 acres located eight miles west of Fresno. The underdrains are in silt and quicksand formation, above which is hardpan.

The Baker Tract contains 20 acres. It is 2 1/2 miles south of Fresno. The underdrains are in silt and quicksand formation, above which is hardpan.

The Dore Tract contains 40 acres and is 7 miles southwest of Fresno. The formation is more or less similar to that of the Baker Tract, but includes less hardpan.

The Modesto Irrigation District is in the San Joaquin Valley between the Stanislaus and Tuolumne rivers. The gross area of the district is 81,183 acres, of which 76,240 is irrigable. In 1927 64,482 acres was irrigated. The land surface is uneven and has a general slope of 5 1/2 feet per mile.

The predominating soils are sandy loam and loam. Hardpan is quite prevalent in the subsoil, beneath which strata of sand are found.

The district contains about 50 miles of drains, but in recent years has turned to pumping from wells as a means of solving the drainage problem. The year of record as given in Table 3 begins with October. During the year the pumps were not operated in November, December and January. The data given for this district include the discharge of 43 miles of drain. The total yield for the year was 39,107 acre-feet, of which 29,267 acre-feet was pumped. The pumped water is used for irrigation. The maximum monthly yield from the gravity drains was in

June and was 0.61 second-foot per linear mile of drain. The average diameter of the wells is slightly over 14 inches, the average depth 100 feet, and the average lift about 24 feet.

The irrigation season begins in March and ends in October. The principal crops are alfalfa, fruit, beans, and grain.

The Merced Irrigation District lies south of the Merced River in the San Joaquin Valley. The gross area is 189,000 acres of which 111,859 acres was irrigated in 1927. The area through which the greater part of the drainage system extends has sandy soil. The subsoils vary and hardpan is found in places. Strata of sand lie at various depths below the subsoil. The land is in general flat but uneven, with swales and potholes. The general slope is from 5 to 7 feet per mile.

This district has an extensive system of shallow open drains, but no records of their discharge are available. Data presented in Tables 3 and 4 relate only to water pumped from wells. About 56 wells were operated in 1927 and the water was used for irrigation, very little being pumped during the winter. The wells have an average depth of 125 feet and an average diameter of 18 inches. The average lift, below the ground surface, is 32 feet.

The irrigation season is from March 1 to October 15.

The Turlock Irrigation District is between Tuolumne and Merced rivers in the San Joaquin Valley. The principal soil is sandy loam. The subsoils contain some hardpan. Below the subsoil strata of sand are found at various depths. The surface is flat though uneven.

This district contains about 73 miles of drains, but in recent years has resorted to pumping from wells. The discharge from the gravity drains is included with that from the wells in the figures given in Tables 3 and 4. During 1927 the total yield was 116,855 acre-feet of which 71,205 acre-feet was pumped. The maximum discharge of the gravity drains, which occurred in August, was 1.1 second-feet per linear mile of drain. The pumped water is used for irrigation. About 69 pumps were operated during the year. The wells have an average depth of 120 feet, an average diameter of 16 inches, and the average lift, below ground surface, is 31 feet.

The irrigation season begins in March and ends in October. The principal crops are alfalfa, grain, beans, and fruit.

Colorado

The Carmel Drainage District is 11 miles northwest of La Jara in the San Luis Valley. The district has an elevation of over 7,500 feet. The average slope is 12 feet per mile. The soil is sandy loam with some clay loam. The subsoil is coarse sand and alluvial gravel. Before the drainage system was installed only 1,330 acres were in cultivation. The drains are uniformly one-half mile apart. The year of record in Table 3 begins with October. The irrigation season for the year of record was from May 1 to August 15. Part of the supply comes from artesian wells and the water is applied by wild flooding. The principal crops are alfalfa, field peas, potatoes and grain.

The Rio Grande Drainage District is located about 9 miles northeast of Monte Vista in the San Luis Valley. The general conditions are

more or less similar to those of the Carmel Drainage District. The drainage system was not completed during the year for which discharge data are given. Drains are spaced about one mile apart.

The Prewitt, Bijou, Shumacher and the Day and Smiley drains are in the South Platte River Valley. The subsoils are generally coarse sand. The drains are shallow and all are below reservoirs from which no doubt they receive most of their water. The upper end of the Prewitt Drain is close to a reservoir embankment. For these drains the year of record given in Table 3 begins with October.

Data are given for a farm near Grand Junction and for two short drains at Canon City. The soil of all three is adobe but the drains reach into shale formation. Most of the discharge comes from small relief wells spaced closely in the shale along the lines of the drains.

Idaho

Ada County Drainage District No. 2 extends along the Boise River, its greater part being east of Middleton. The district comprises 31,000 acres 18,000 acres of which is low land. The soil is sandy loam underlaid at a depth of from 2 to 7 feet with gravel and coarse river sand. The irrigation season begins in April and ends in September. The drainage discharge records are for the irrigation season only.

Ada County Drainage District No. 3 extends along the Boise River and includes a part of South Boise. It has a general slope of more than 20 feet to the mile. The soil is sandy loam underlaid at a depth of from 3 to 4 feet with gravel and sand. Portions within the city limits are not well cultivated. The drainage system is not well maintained. The irrigation season begins in April and ends in September, and the drainage discharge records cover only that period.

Ada County Drainage District No. 4 is just west of Boise and south of the Boise River. The drainage district proper is river-bottom land, but higher bench lands contribute water. The soil is sandy loam underlaid by gravel and sand. For some distance the drain closely parallels an irrigation canal. The drainage discharge records cover only the irrigation period - April to September.

Blaine County Drainage District No. 1 extends along Silver Creek and is adjacent to the town Picabo. It has a slope of from 8 to 10 feet per mile and is traversed by sloughs. The prevailing soil is a dark loam and the subsoil is gravel which in some places is cemented. Lava rock is near the surface in some places, particularly along a part of the lower boundary of the district. Seepage conditions are affected by underground flow from a portion of the Wood River Valley.

Franklin County Drainage District No. 3 is near Banida. Data on a portion of the district show the soil to be clay and clay loam underlaid at a depth of a few feet by a little sand beneath which is clay. The main crop is wheat. The irrigation supply is limited and only a very small quantity of water is used. The drainage yield is very low; in fact, per linear mile of drain, it is the lowest of any presented.

Canyon County Drainage District No. 1 extends along the Payette River about 10 miles below Emmett. It is largely river bottom land broken by small depressions. Two large canals are located along the bluffs which border one side of the district. The prevailing soil is silty loam. About 75 per cent of the drainage system reaches into gravel; the remainder is in clay and sandy loam. The district is not

well cultivated but is supplied with an abundance of irrigation water.

Canyon County Drainage District No. 2 is about 2 miles from Payette. For the most part it consists of bottom land along the Snake River. The subsoil is sand and gravel. Discharge data are available for only a part of the system.

The Minidoka Project (North Side Gravity Unit) extends along the Snake River and includes the towns of Heyburn and Rupert. The land is flat with irregular slopes, the average general slope being about 1 foot per mile.

The soils are sandy loam, fine sandy loam, and sand. The subsoils vary from medium to coarse sand, and gravel is found in a few places.

The irrigation season begins in April and ends in October. The water from Drain D-12 is pumped and used for irrigation. The duty of water within the district varies widely. The principal crops are alfalfa, grain, sugar beets, and potatoes.

Payette County Drainage District No. 1 extends along the Snake River near Payette. It adjoins Canyon County Drainage District No. 2. The soil is sandy loam and the subsoil is sand and gravel.

The Pioneer and Nampa-Meridian District is in the Boise Valley and includes the towns of Caldwell and Nampa. The area consists of two benches -- the Boise River Bench and the Second Bench, the latter comprising 36 per cent of the total area. The land is rolling, and lava rock is encountered in many places a few feet below the ground surface. A stratum of sand and gravel is encountered at depths varying from 2 to 40 feet, often below a layer of rock. Hardpan is prevalent.

Except for the natural water channels, the drainage system does not extend into the Second Bench. The general slope of the Boise Bench is from 10 to 12 feet per mile. Deep drains have been constructed in the natural drainage channels except the main channel of Indian Creek which serves as a drain without alteration. The drains are of the relief type and topography governs their location. Occasionally during the winter months the drains carry some flood waters which come down from the natural channels. This is particularly true of Five Mile and Indian creeks.

The formation along the West End Drain consists chiefly of coarse sand with gravel at the upper end. Along the Dixie Drain it is coarse washed sand with a stratum of clay and fine sand, the former predominating. Some gravel exists.

The area served by the Wilson System is separated from the Deer Flat Reservoir by a ridge, except for that portion served by the Upper Embankment Drain, which is located near the reservoir. The formation consists of coarse washed sand underlying the top soil at a depth of a few feet, or underlying clay soil at a somewhat greater depth. Gravel and sand are encountered along the upper part of the Upper Embankment Drain. There is not much hardpan, but lava rock is near the surface along two miles of the system.

Much lava rock is in the area served by Indian Creek. The water-bearing formation is a coarse granite sand along the natural channel but in many places the channel does not reach into it. The drains tributary to Indian Creek are in coarse washed sand, or in clay and fine sand.

The Mason Creek System reaches into gravel and sand which are under the top soil at a depth of a few feet. The gravel and sand are well graded and compact. There is little or no hardpan.

The Five Mile Creek System reaches into extensive strata of gravel and sand which is well graded and very compact. Hardpan is found in some places.

The irrigation season begins in April and ends in October. The principal crop is alfalfa.

The Tucker Tract is a 40-acre farm near Notus. The top soil is a light sandy loam and the subsoil a heavier sandy loam which has become hardpan to some extent. The drainage system receives some water from land beyond the boundary of the tract.

Boise Project, Lower Division. Some of the drains included under this heading are not within the Boise Project but are just below it. Some of them extend into the project and for this reason all have been considered as belonging to the same area. Part of this area extends into Oregon and its lower end is at the confluence of the Snake and Boise rivers. It consists of bottom land above which is a rolling bench.

The subsoils vary widely and consist of gravel, sand, and what is locally called shale. A considerable part of the area in Oregon is underlaid by shale. Gravel is found under much of the remainder, but is not always reached by the drains. The sandy top soil is directly underlaid by a sandy clay or with alternate strata of sand and clay. The maximum depth of the drains is about 17 feet.

The Fargo Basin, which includes the Laht and Griffith drains, has benches with rolling topography and an average general slope of 40 feet per mile. The subsoil is generally sand and gravel.

The Dotson and Lower Embankment drains extend to the lower embankment of the Deer Flat Reservoir.

The Lowell Drain reaches into gravel and coarse sand throughout its length, and has a maximum depth of 14 feet.

The Ross Drain is at the foot of a terrace, and gravel is near the surface as is also the case along the Sterry and Allen drains, the maximum depth of which is 15 feet.

The Singer System is on low ground and the formation is mostly a poor water-bearing material locally called shale.

Along the Welch Drain the top soil is very sandy, and is underlaid by fine sand mixed with silt except in some places where it is underlaid by clay.

The irrigation season begins in April and ends in October.

Montana

The Huntley Project extends along the Yellowstone River and includes the towns of Ballantine and Worden. The land is flat with well defined breaks. The average slope is from 8 to 10 feet per mile.

The soil varies from very heavy clay to light sandy loam. At grade depths the subsoil is clay, sand, and gravel. The majority of the drains reach into gravel and sand, but frequently the permeable formations are not continuous and consist of lenses surrounded by tight materials. Along many drains the formation above the sand and gravel is tight clay. As compared with that of other projects, the duty of water is very high. All of these factors tend to make the yield of the drains relatively low. Although both relief and interceptive types are used, topography governs the location of the drains. Complete records on discharge were available for 1914 and 1915. The data for

1925 were obtained by single measurements only. For the individual drains the discharges shown exceed those of any previous record.

The irrigation season begins in May and ends in September. The principal crops are alfalfa, grain, and sugar beets.

The lower Yellowstone Project is in Eastern Montana and Western North Dakota. The drain listed in Table 4 has relieved seepage conditions on 1,000 acres. Not much land is irrigated along the open drain.

Nebraska

Lincoln County Drainage District No. 1 is on the South Platte River, and the lower end of the district is about 3 miles west of the town of North Platte. The land is flat and irregular, and parallel with the river the average slope is 7.5 feet per mile. The district is about 12 miles long. The distance between the South Platte and North Platte rivers is about 3 miles and the latter is lower than the former. The soil is a loam immediately below which is a clay loam or heavy sandy clay. The drains extend into a formation of coarse sand with some gravel.

Both the annual and maximum yields per square mile are among the highest listed in the tables. Probably the yield is affected to a considerable extent by losses from the South Platte River. Frequently heavy precipitation occurs during the summer months.

The North Platte Project extends along the North Platte River in Nebraska and Wyoming. The topography is rolling and the average slope is 15 feet per mile: Along the Dunham-Andrews and the Winters Creek drains the slopes are 21 and 26 feet per mile, respectively. The soil varies from sandy loam on the greater portions of the Interstate and

Northport Divisions, to gumbo on portions of the Ft. Laramie Division. On a considerable part of the project the subsoil is Brule clay, a compact silty material containing much fine sand. When unbroken it is quite impervious, but often it is fissured to such an extent that water moves through it freely.

Some of the total areas include a considerable amount of unirrigable land. The drains are mostly of the relief type, and are situated in valleys. The majority are open drains. Discharge data for some drains were not included in the tables, since it appeared that they carried a considerable amount of direct waste. Data for drains on the Interstate Division do not include the outlets which cross lower areas outside the project. Data for all other drains are for a point at or near the outlet into the river. Some of the drains have natural tributary channels which may pick up some seepage water. This is particularly true of the Sheep Creek, Dry Spotted Tail and Indian Creek drains. The Winters Creek, Alliance, and Minatare drains are below reservoirs which probably contribute seepage water to them.

The irrigation season begins in April and ends in October. The principal crops are alfalfa, cereals and sugar beets.

Nevada

The Newlands Project is located on the delta of the Carson River. The principal town is Fallon. The surface might be described as a series of potholes or depressions separated by ridges. The slope of the tract is slight, averaging only about 4 feet to the mile. The soils are deep and very spotted and vary from light sandy soils to clay and adobe. The more pervious soils are, with few exceptions, in the upper parts of

the project. The predominating soil on the North Carson Division is sandy loam and the subsoils are sandy. In the South Carson Division the soils and subsoils vary widely, but for the most part are heavy. The Truckee Division has steeper slopes and some of the soils are gravelly loam. The subsoils are sandy with some gravel.

Prior to the installation of the deep drains a shallow drainage system was constructed. These shallow drains serve merely to carry off farm waste and are not included in the mileage given in the tables.

The irrigable lands are more or less scattered. The irrigation season is from April 1 to October 15. The principal crops are alfalfa, grain, and potatoes.

New Mexico

The Carlsbad Project lies on the Pecos River in the southeastern part of the State. The surface is rather even, and the average slope is 12 feet per mile. The soil is clay and sandy loam while subsoils are gypsum, sand, and gravel. Drains are interceptive. The irrigation season is long. Principal crops are cotton, alfalfa, grain, and fruit.

The Rio Grande Project extends along the Rio Grande in New Mexico and Texas. The El Paso Division is in Texas, its principal town being El Paso. The project consists of river-bottom lands skirted by bluffs, and varies in width from 1 to 5 miles. The river is very crooked and the channel is wide, shallow, and quite sandy. The river's bed is generally from 4 to 8 feet below the bordering lands, but often the land slopes away from the banks and in a few places the bed is slightly higher than portions of the valley. The ground surface is flat except where broken by small sand hills or cut by old river washes. The general slope of the valley is from 4 to 5 feet to the mile. The character of the soil shows great variation, the chief materials being sand and silts;

these materials exist in spots and pockets. Frequently thin laminations of silt are found at intermediate depths. Sand grading from medium fine to quicksand is found practically everywhere from 6 to 10 feet below the surface.

Before drainage was undertaken about 70 per cent of the project was affected by a high water table. Some of the drains are near the river, while others are back near the bluffs. They are generally long and more or less parallel with the river. The Rincon Division shows a greater annual drainage yield than the other divisions. It receives more irrigation water than the others although the supply is not greatly in excess of that used on the El Paso Division. The Rincon Division is narrow and the drains are near either the river or a canal, or both, the Hatch Drain particularly being near the river. On the Mesilla Division the Del Rio, Leasburg, and West drains have high maximum discharges. The Del Rio Drain, except for one branch, is all on low ground and is near the river. Part of the Leasburg Drain is near a canal, and the remainder is near the river. The West drain is close to the bluffs and remote from the river. The Mesilla and Anthony drains have low discharges. Part of the Mesilla Drain is near the bluffs and part is between two other drains. The Anthony Drain runs through a wide section, and another drain is located between it and the bluffs. On the El Paso Division, drains having high maximum discharges are the Fabens and Playa; both are near the river and near an irrigation lateral. The Island and Border drains have low maximum discharges. A part of the former is between two drains and the latter is near the bluffs at a considerable distance from the river.

Water is diverted during 11 months of the year although the quantity is rather small during the winter months. The principal crops are cotton, alfalfa, corn, cane, melons and garden truck.

Oregon

The Klamath Project is at Klamath Falls. The land is flat and has an average fall of 3 feet to the mile. The predominating soil is sandy loam underlaid by hardpan, a diatomaceous formation, and fine sand. The area considered in the various tables is traversed by Lost River which serves as an outlet for the drains; it also carries irrigation water. The length of drain given in the tables includes this natural channel. The discharge is influenced by a small reservoir on the lower part of Lost River, which fact accounts for the irregular monthly yield for a portion of the year as shown in Table 1.

The irrigation season begins in May and ends in September. The year of record for drainage yield given in Table 1 begins with October. The principal crops are alfalfa and grain.

The Nyssa-Arcadia Drainage District extends along the Snake River near Nyssa. Fine sandy loam is the predominating soil which quite generally is underlaid by hardpan 3 to 5 feet thick. Under this hardpan there is usually found a thin stratum of quicksand. The lower 2 1/2 miles of main drain is in a very hard, close-textured, sandy clay soil. The remainder of the system penetrates into a layer of fine sand, and in a few cases reaches gravel. The irrigation season begins in April and ends in October. The principal crops are alfalfa, grain, and fruit.

The Umatilla Drainage District includes the town of Stanfield. It consists of a small valley bordered on three sides by two irrigation canals. One of these carries water during the irrigation season and the other during the winter months. The slope varies from about 5 feet per mile at the lower end of the valley to 50 feet per mile at the upper end. The soil ranges from fine sandy loam on the lower part to coarse soil with traces of gravel at the upper end. At the lower end hardpan exists to a considerable depth but the greater part of the main drain reaches into gravel and sand. In 1923 the irrigation season extended from March 10 to July 25. In 1924 it was from March 7 to June 1.

The Umatilla Project is located in northeastern Oregon and includes the towns of Hermiston and Umatilla. The Main Drain, which is the only one considered in Tables 3 and 4, is in a valley of rolling topography, and the average slope is 6 feet per mile. The soil is sand and sandy loam underlaid by sand and some gravel. The irrigation season begins in April and ends in October. The principal crop is alfalfa.

The lower end of the Main Drain is very deep and reaches into gravel. The greater part of the system has less depth and the predominating subsoil is sand with some gravel. The drainage yield, in percentage of water applied, is the highest listed in Table 3 and it is difficult to identify the source of all of it. It is possible that the seepage loss from the Cold Springs Reservoir is greater than the estimated amount, and perhaps the precipitation figures should have been based upon an area greater than that irrigated. The discharge recorded on a section one mile long at the lower end of the main drain (Table 4) is by far the highest as to yield per linear mile.

In the case of Utah, records were not available on total annual yields of drains nor on the quantity of water applied. The duty of water is said to vary from 1.5 to 4 acre-feet per acre, with 2.5 to 3.5 acre-feet per acre as a fair average. The principal crops are alfalfa, sugar beets, and grain. In general the surface soils do not differ structually from the subsoils. Both vary widely for most of the drains and this makes it difficult, and frequently impossible, to report the predominating subsoil for each case. A very common type of subsoil consists of clay or sandy clay with layers of sand.

In many instances figures on the area irrigated are not given and in some cases the unit discharge per square mile, as given in Table 3 was computed on the basis of total area. For a considerable number of the drains the area irrigated is a low percentage of the total area, because the discharge measurements were made before the land had fully recovered from the conditions existing prior to drainage. The usual depths of the drains listed range from 5 1/2 to 8 feet, and they are spaced from 400 to 1,300 feetapart. Close spacing partly accounts for the low discharge per linear mile of drain. Moreover, surface waste is not admitted to underdrains.

Millard County Drainage District Nos. 1, 2, 3, and 4 are located in the Pahvant Valley near Delta. District No. 3 has an area of 44,000 acres. The valley is flat, the general slope being 5 feet per mile. The soils vary widely, with clay loam and sandy loam predominating along the drains listed in Table 4. The subsoils vary from clay to sandy clay with layers of sand. Alfalfa seed is an important crop in this valley.

The Sevier County, San Pete County and Redmond drainage districts are on the Sevier River in the vicinity of the towns of Richfield, Gunnison, and Redmond, respectively. The slopes are generally slight on the lower parts of these districts, and much steeper on the upper parts of some of them. It seems probable that in some cases the areas reported do not include some of the higher land which may be tributary to the drains. Soils on the lower portions are clay and sandy clay loam. With respect to subsoils, considerable gravel is found in San Pete County Drainage District No.1 and sand and gravel in Sevier County Drainage Districts Nos. 2 and 3. Some gravel is found in Sevier County Drainage District No. 6. Predominating subsoils on the other districts are clay and sand.

The Benjamin, Lake Shore and Benjamin, Lake Shore and North Drainage Districts, and Utah County Drainage District No. 1, are situated on or near the southern shore of Utah Lake and near the town of Spanish Fork. The predominating soil is clay loam, with lighter soils on the ridges. Predominating subsoils are clay and sandy clay with layers of sand. Sand subsoil is more prevalent in the Benjamin district than in the others.

The Elwood Drainage District extends along the Bear River and is about 9 miles northwest of Brigham City. The soil is loam with some fine sandy loam. The subsoils are clay loam and clay. The land is flat, This district is largely cultivated.

Davis County Drainage District No. 1 and the Brighton Drainage District are near the shore of Great Salt Lake and not far from Salt Lake City. The surface is flat. The soils are loam and clay, and the subsoils are clay and clay loam.

The Jensen Tract is in the vicinity of Murray. It consists of 20 acres but has additional tributary area. The subsoil is gravel.

The Swan Tract is located 4 miles west of Salt Lake City and contains 40 acres. The soil is silty and sandy loam, and the subsoil is heavy clay with a shallow sand stratum at a depth of 4 feet. Hardpan exists on the lower half of the tract.

The Webb Tract is near Riverton and contains 10 acres. Other irrigated land is tributary. The soil is sandy loam, and the subsoil is loose sand and fine gravel.

Washington

Yakima County Drainage Districts. Districts Nos. 28 and 33 are in the Naches Valley near the town of Naches. Districts Nos. 4, 11, 13, 24, 29, and 38 to 42, are in the vicinity of Yakima. All others listed under this heading are in the Sunnyside Division of the Yakima Project.

The topography is generally rolling; the ridges and draws are well defined, leaving little choice in the location of a drainage system. The slopes vary widely and generally are flat on the lower portions of the districts; on the upper portions the land is quite rolling with slopes, in some cases, of over 100 feet per mile. Soils vary from sand to heavy silt, but the majority are sandy loams. Subsoils vary from clay and hardpan to sand and gravel. The hardpan is a tight silt or clay formation, not calcareous. A common type of subsoil on the Sunnyside Division consists of alternating layers of hardpan and fine sand or hardpan with sand pockets.

On the Sunnyside Division the irrigation season begins with April and ends with October. The principal crops are alfalfa, fruit, grain, and potatoes. The furrow or corrugation method of applying water is used.

Rotation is not generally practiced. The water application in districts Nos. 38, 40 and 41 is light as compared with that in the Sunnyside Division. The application of water in districts Nos. 7 and 12 is heavy; in Nos. 13, 28, 33, 39 and 42 it is very heavy, and it is possible that some of these districts have a greater tributary area than is generally indicated by the ground surface topography.

The land of districts Nos. 13, 28, 33, 39 and 42 is rather flat; the soil is gravelly loam, and the subsoil is gravel.

Districts Nos. 3, 5, 9, 17, 18, 19 and 20 are tributary to the Sulphur Creek wasteway which serves as an outlet and a deep drain. The predominating soil of the majority of these districts is sandy loam. They are relatively flat at their lower ends and have rolling topography at the upper ends. Of this group District No. 3 is the flattest and has the smallest amount of sandy loam soil.

Districts Nos. 7 and 12 have flat topography. The soil on the upper portions is sandy and on the lower portions it is a heavy silt loam.

Districts Nos. 2, 25 and 27 are rolling. No. 27 has a good deal of sandy soil and the other two a considerable amount of loam.

District No. 15 has rolling topography. The soil is fine sandy loam on the ridges and a silty loam in the draws. It appears that the earth around the underdrains is so puddled that water does not enter them freely.

District No. 16 is rather flat and has a considerable amount of silt loam soil.

District No. Joint 1 has silt loam and fine sandy loam soil. The land is flat with depressions, and water from the drainage system has to be pumped.

All of the underdrains and open drains in Yakima County carry surface waste from farms. The Sulphur Creek Wasteway carries much direct waste from canals and laterals, but its amount has been deducted from the discharge figures listed. For all Yakima County drains shown in Table 3, the year of discharge record begins with April.

The Wapato Project is on the Yakima Indian Reservation. The principal towns are Toppenish and Wapato. Toppenish Creek is near the southern boundary of the area considered, and the Yakima River forms the eastern and northeastern boundary. At the northeastern boundary the Yakima River is higher than much of the southern portion of the project and this no doubt has a considerable bearing on the underground water conditions.

The land is generally flat, and although it is somewhat uneven it has been possible to locate drains more or less uniformly along subdivision lines. To a considerable extent the drains are interceptive. The soils are generally a sandy or gravelly loam but heavier soils predominate in the eastern and southern portions. Except in the eastern portion the soil blanket is generally thin and is underlaid by coarse gravel to a considerable depth.

On the upper and northern portions of the project the depth to the water table varies widely with the seasons and some drains which show very heavy discharge during the irrigation season are dry during the winter months. Drains Nos.1, 2, 3, and 4 are all in coarse gravel and closely parallel large irrigation laterals; in fact the spoil from the drains was used to build the banks of the laterals. For all drains on this project the year of record for discharge given in Table 3 begins with March.

Although some water is diverted during March the irrigation season usually begins with April and ends with October. A considerable portion of the drainage water is used for irrigation on the project, and this has been included both in the total yield of the drainage system and in water diverted to the project. The principal crops are alfalfa, grain, and potatoes.

The Yakima City Westside Drain is deep and is located in gravel, some of which is very coarse. No surface water is admitted to this drain and the discharge shown is all seepage water.

Wyoming

The North Bench Drainage District is in the Big Horn Basin immediately north of the town of Basin. The soil is clay loam, and gravel is usually encountered at drainage depth. The gravel is well compacted, the interstices being filled with fine material. A considerable part of the area considered was not cultivated.

The Wyoming Experiment Station is located near Laramie. The drained area contained 80 acres, but higher irrigated land was tributary. The soil is thin and is underlaid by a coarse sandy gravel.

The Shoshone Project extends along the Shoshone River. Powell is the principal town. The tract ranges from comparatively flat land with benches, to rolling. General slopes vary from 25 to 35 feet per mile on the lower portions of the project, but are much steeper on some of the higher parts. The soil varies from light sandy loam to heavy clay. The subsoils vary from gravel to shale.

Area No. 1 is on the first bench. The soil is sandy clay and the predominating subsoil is black gravel. About 2 miles of the drains are in quicksand.

Area No. 2 is on the second bench and along a large canal. The soil is sandy clay and the subsoil is black gravel.

Area No. 3 is on low land. The soil is sandy clay and the subsoil is black gravel.

Area No. 4 has sandy clay soil of somewhat greater depth than that of areas 1, 2 and 3. The predominating subsoil is black gravel, but about 4 miles of the drains are in gravelly sand and sandy clay.

Area No. 5 is just below an irrigation lateral. The predominating subsoil is in gravel. Some sand and shale are also found.

Area No. 6 is high and contains steeply sloping land crossed by two main laterals. The soil and subsoil are sandy clay.

Area No. 7 is high and includes steeply sloping land. The subsoils are quicksand, shale and sandrock.

Area No. 8 is below a small reservoir.

Area No. 9 is low land, and clay predominates.

For 1923 the irrigation season began with May and ended with September. The principal crops were alfalfa, grain, potatoes, and sugar beets.

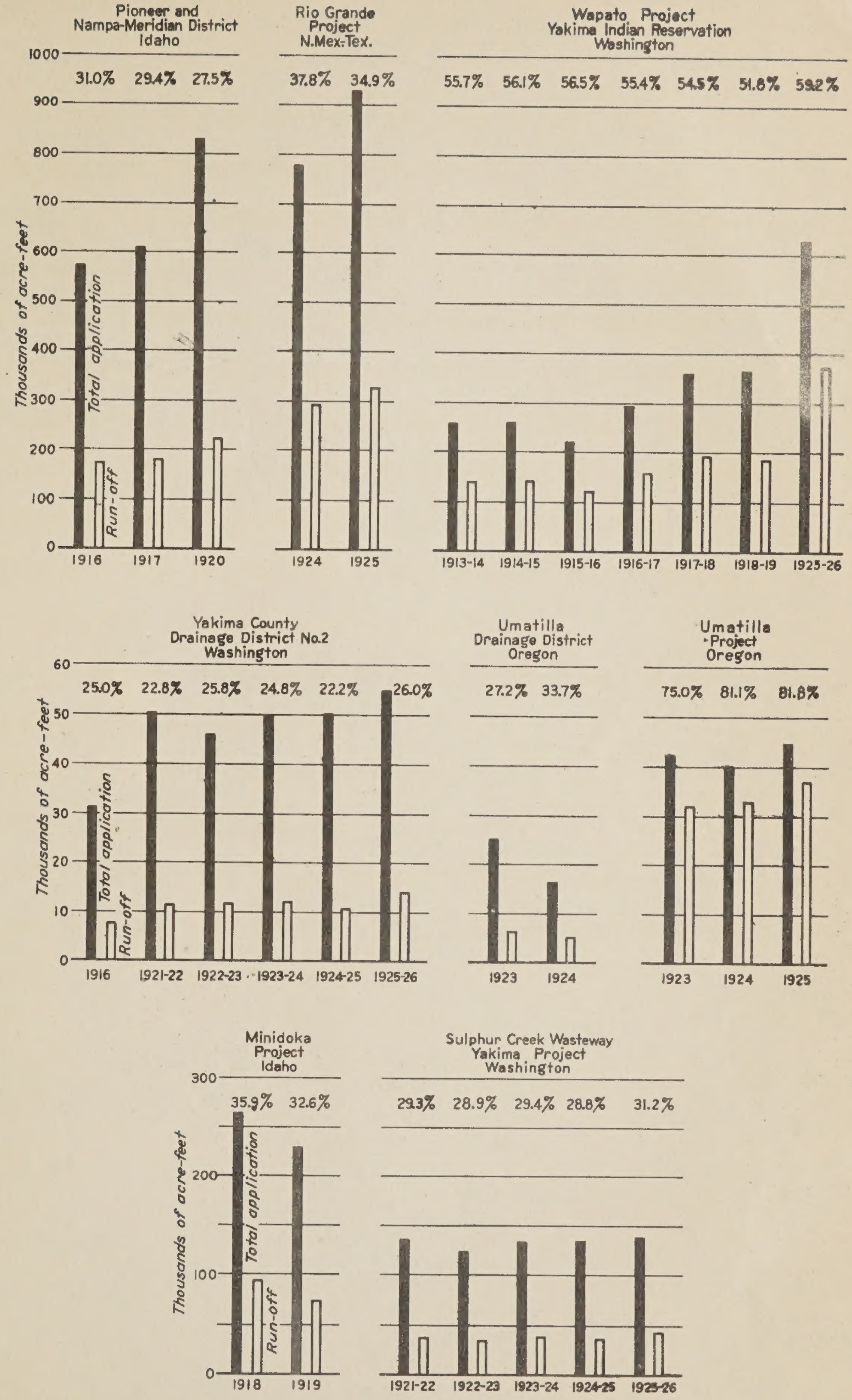

Fig. 1.— Relation of total annual run-off to total irrigation water applied plus precipitation